

(12) **United States Patent**  
**Park et al.**

(10) **Patent No.:** **US 10,980,517 B2**  
(45) **Date of Patent:** **Apr. 20, 2021**

(54) **ULTRASONIC DIAGNOSTIC APPARATUS FOR ESTIMATING POSITION OF PROBE AND METHOD FOR CONTROLLING THE SAME**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 599 days.

(21) Appl. No.: **15/861,491**

(22) Filed: **Jan. 3, 2018**

(65) **Prior Publication Data**  
US 2018/0235580 A1 Aug. 23, 2018

(30) **Foreign Application Priority Data**  
Feb. 23, 2017 (KR) ..... 10-2017-0024035

(51) **Int. Cl.**  
**A61B 8/00** (2006.01)  
**A61B 8/14** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **A61B 8/54** (2013.01); **A61B 8/145** (2013.01); **A61B 8/4245** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... G01S 15/8915; G01S 15/8936; G01S 15/8979; G01S 15/8984; G01S 15/899;  
(Continued)

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*Primary Examiner* — Amelie R Davis

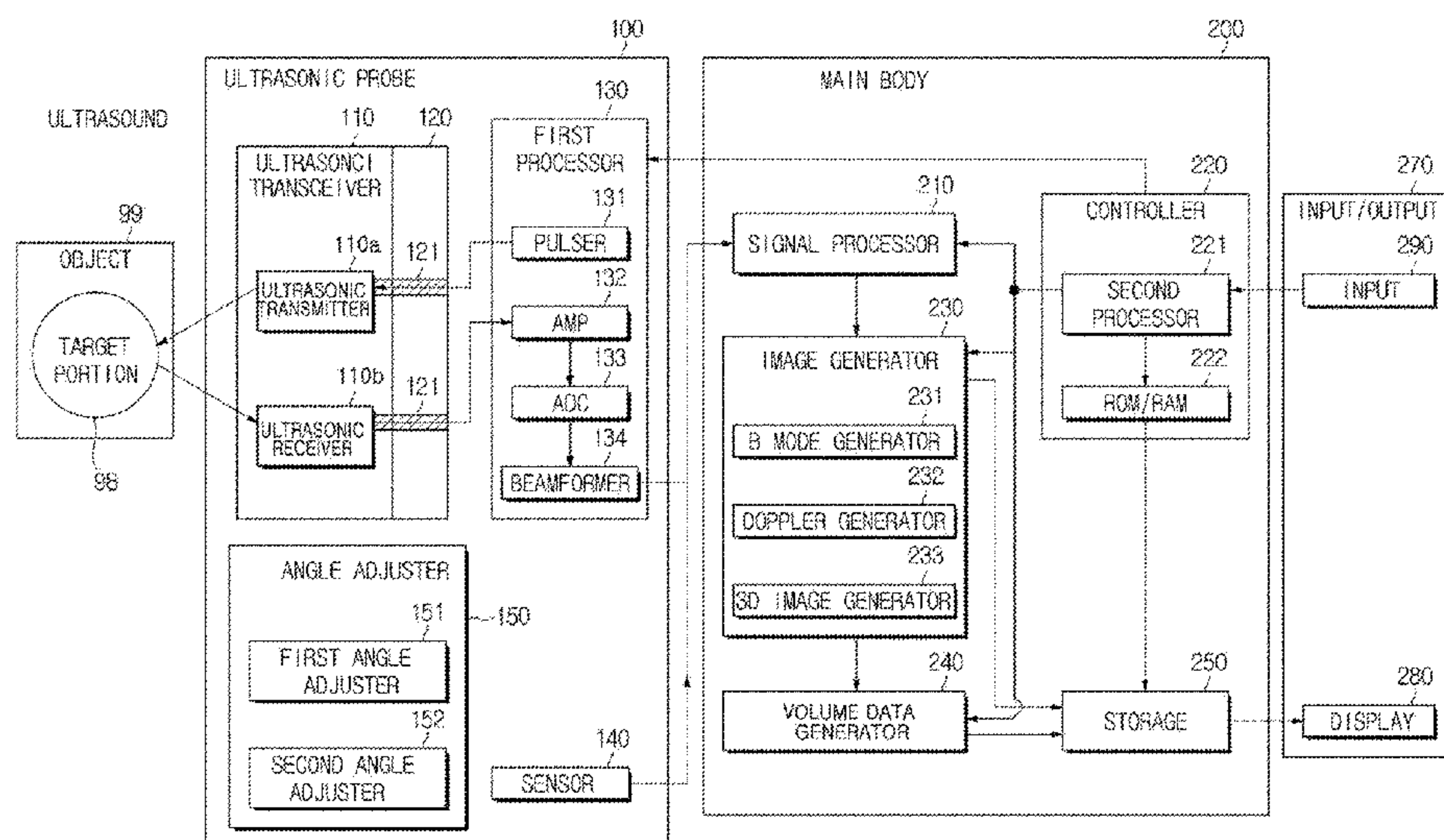
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(57) **ABSTRACT**

In accordance with an aspect of the present disclosure, there is provided an ultrasonic diagnostic apparatus comprise an ultrasonic probe configured to transmit an ultrasound signal to an object and receive a response signal reflected from the object, an image generator configured to create an ultrasound image of the object based on a first ultrasound signal and a first response signal and a controller configured to control transmission order and transmission intervals of the ultrasound signal and estimate a position of the ultrasonic probe based on a second ultrasound signal and a second response signal.

The ultrasonic diagnostic apparatus in accordance with embodiments of the present disclosure, the current position of the ultrasonic probe is estimated using an ultrasound signal transmitted for creation of an ultrasound image without attachment of an extra sensor, so the position of the ultrasonic probe may be estimated more economically and effectively.

**14 Claims, 15 Drawing Sheets**



(51) **Int. Cl.**  
*A61B 8/08* (2006.01)  
*G01S 15/89* (2006.01)  
*G01S 7/52* (2006.01)  
*A61B 34/20* (2016.01)

(52) **U.S. Cl.**  
CPC ..... *A61B 8/4254* (2013.01); *A61B 8/4444* (2013.01); *A61B 8/4488* (2013.01); *A61B 8/52* (2013.01); *A61B 8/5207* (2013.01); *G01S 7/52074* (2013.01); *G01S 15/8915* (2013.01); *G01S 15/8936* (2013.01); *G01S 15/8979* (2013.01); *G01S 15/8993* (2013.01); *A61B 8/4405* (2013.01); *A61B 8/483* (2013.01); *A61B 8/488* (2013.01); *A61B 2034/2048* (2016.02); *A61B 2034/2065* (2016.02); *G01S 7/52085* (2013.01); *G01S 15/899* (2013.01); *G01S 15/8984* (2013.01)

(58) **Field of Classification Search**  
CPC ..... G01S 15/8993; G01S 7/52074; G01S 7/5208; A61B 2034/2048; A61B 2034/2065; A61B 8/145; A61B 8/4245; A61B 8/4254; A61B 8/4405; A61B 8/4444; A61B 8/4488; A61B 8/483; A61B 8/488; A61B 8/52; A61B 8/5207; A61B 8/54

See application file for complete search history.

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**FIG. 1**

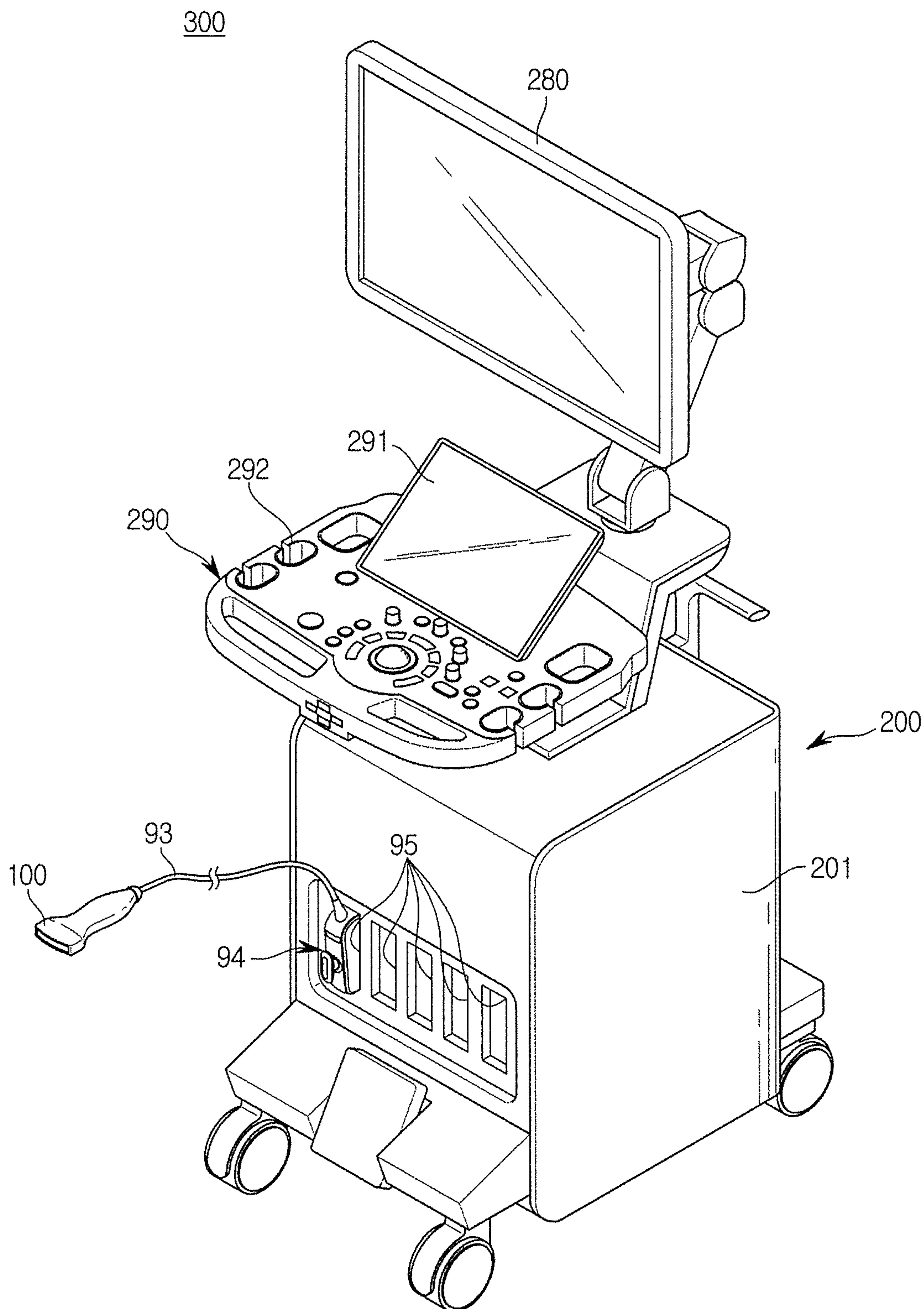




FIG. 2

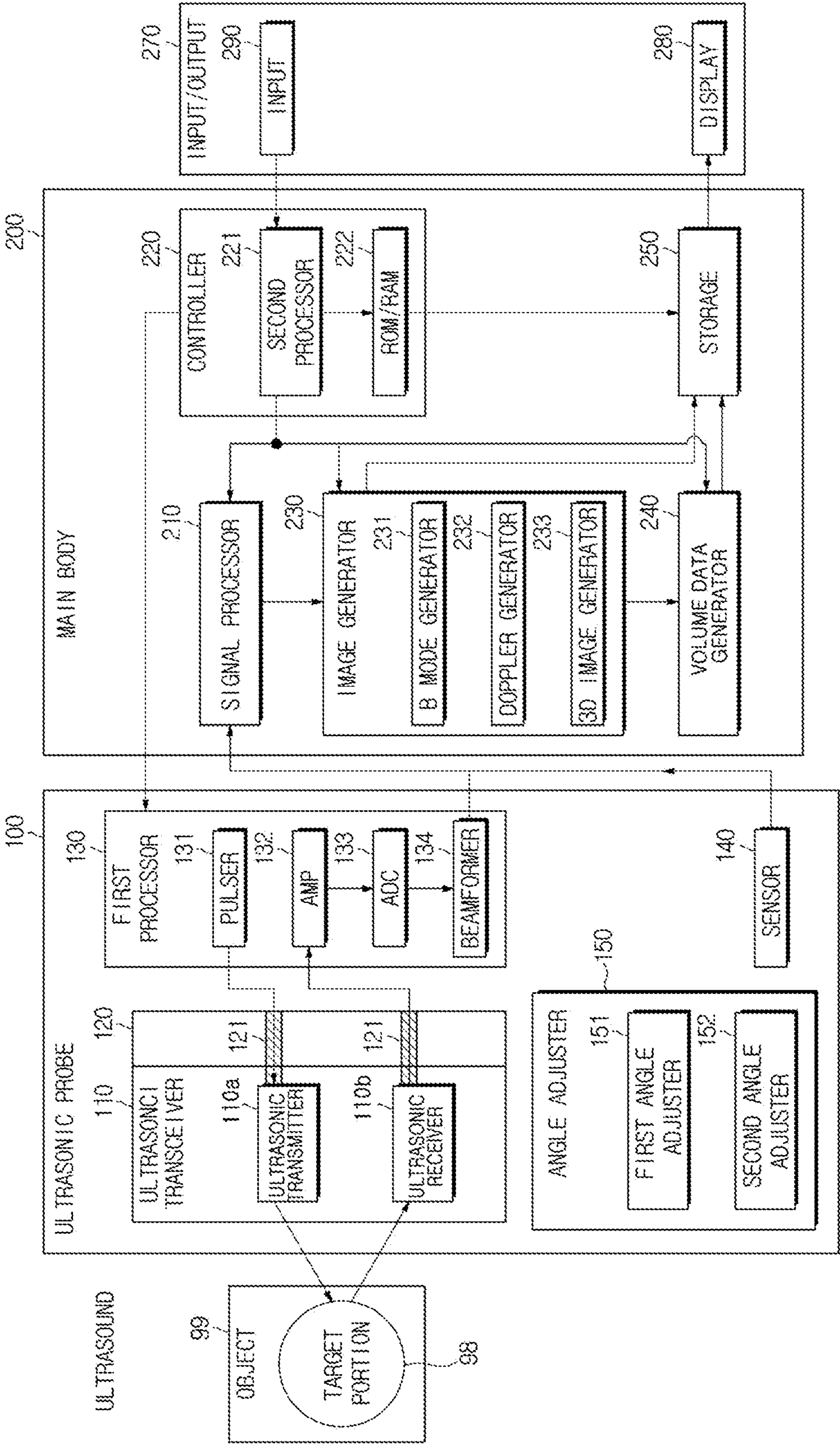


FIG. 3A

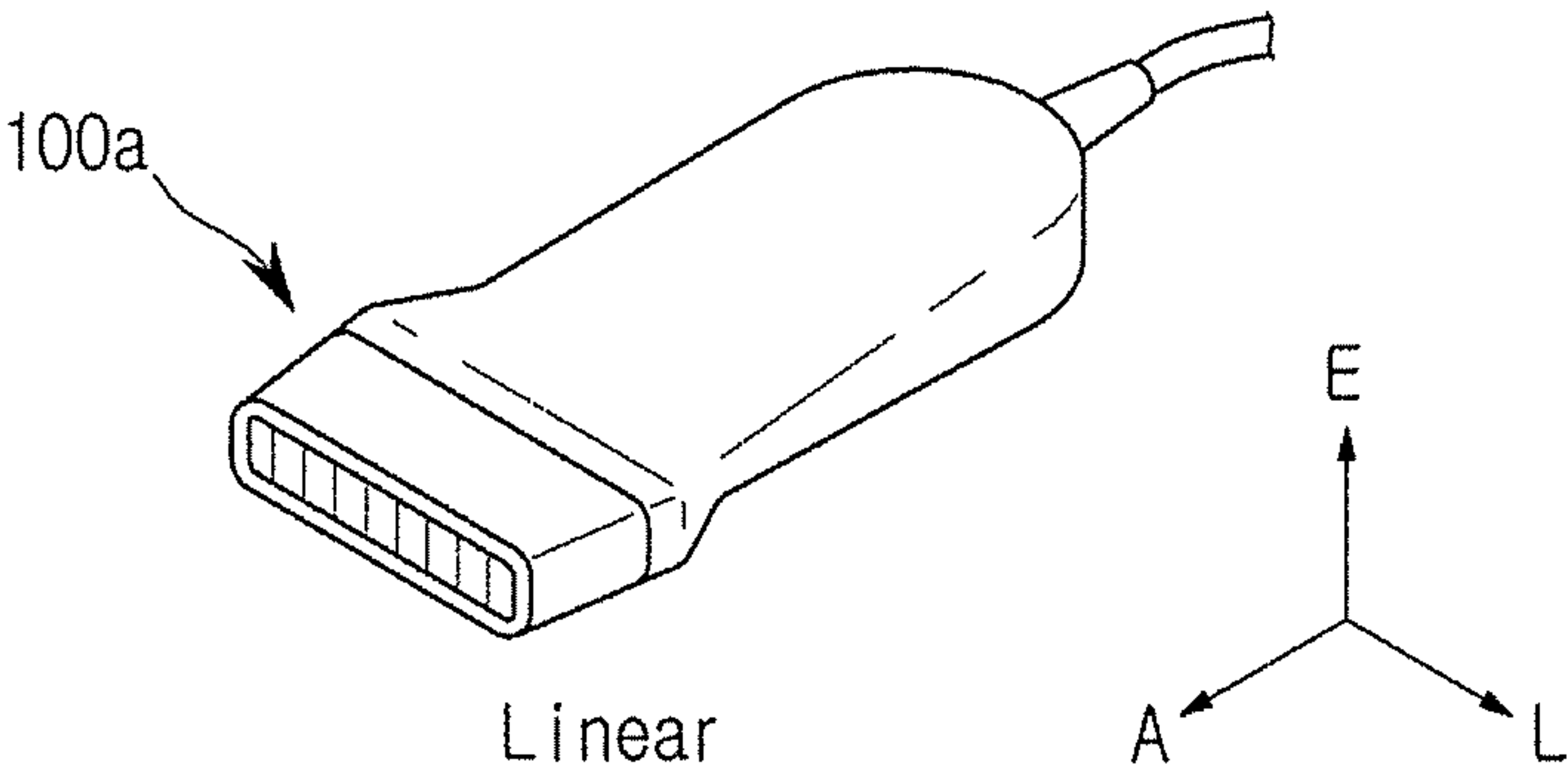
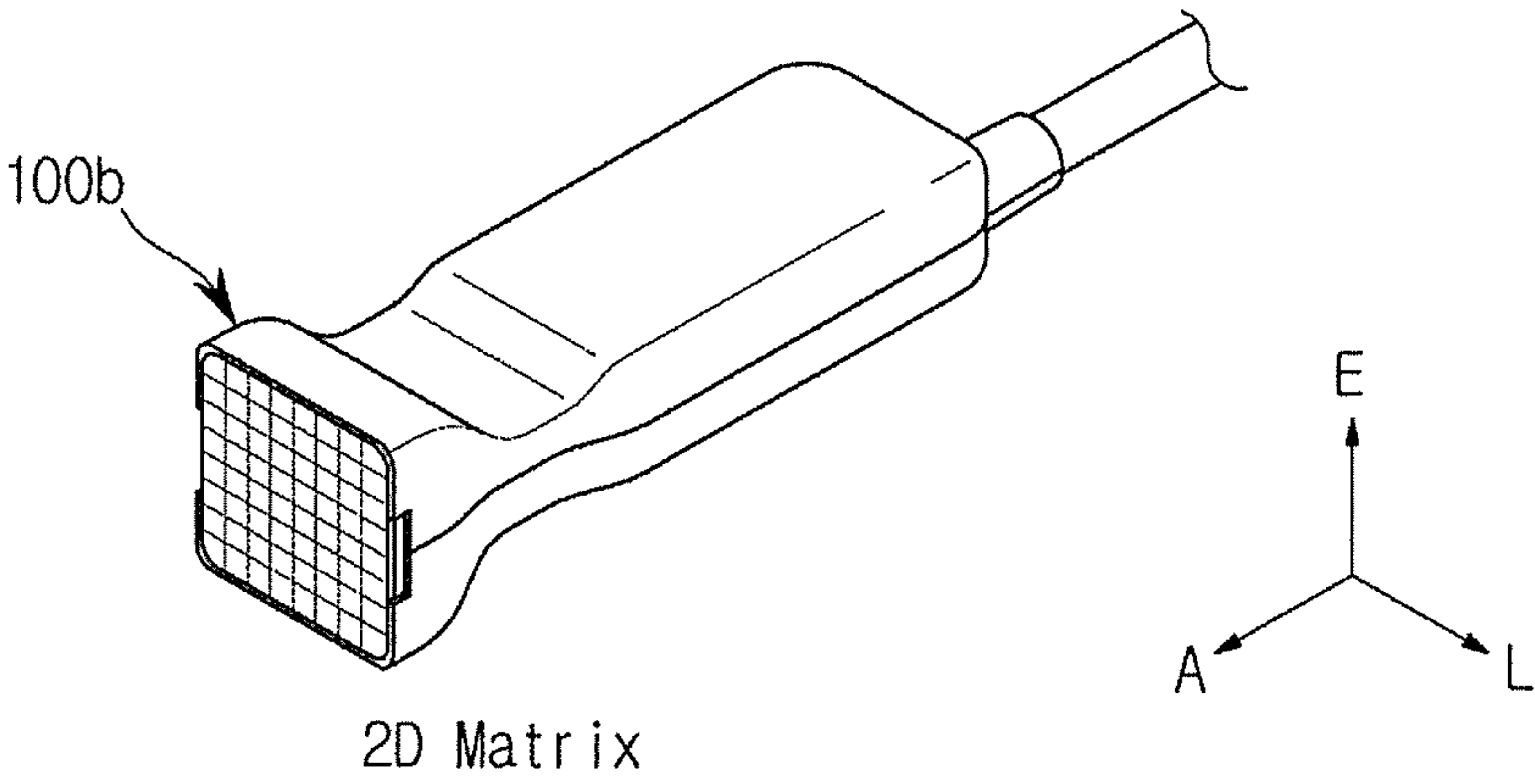


FIG. 3B



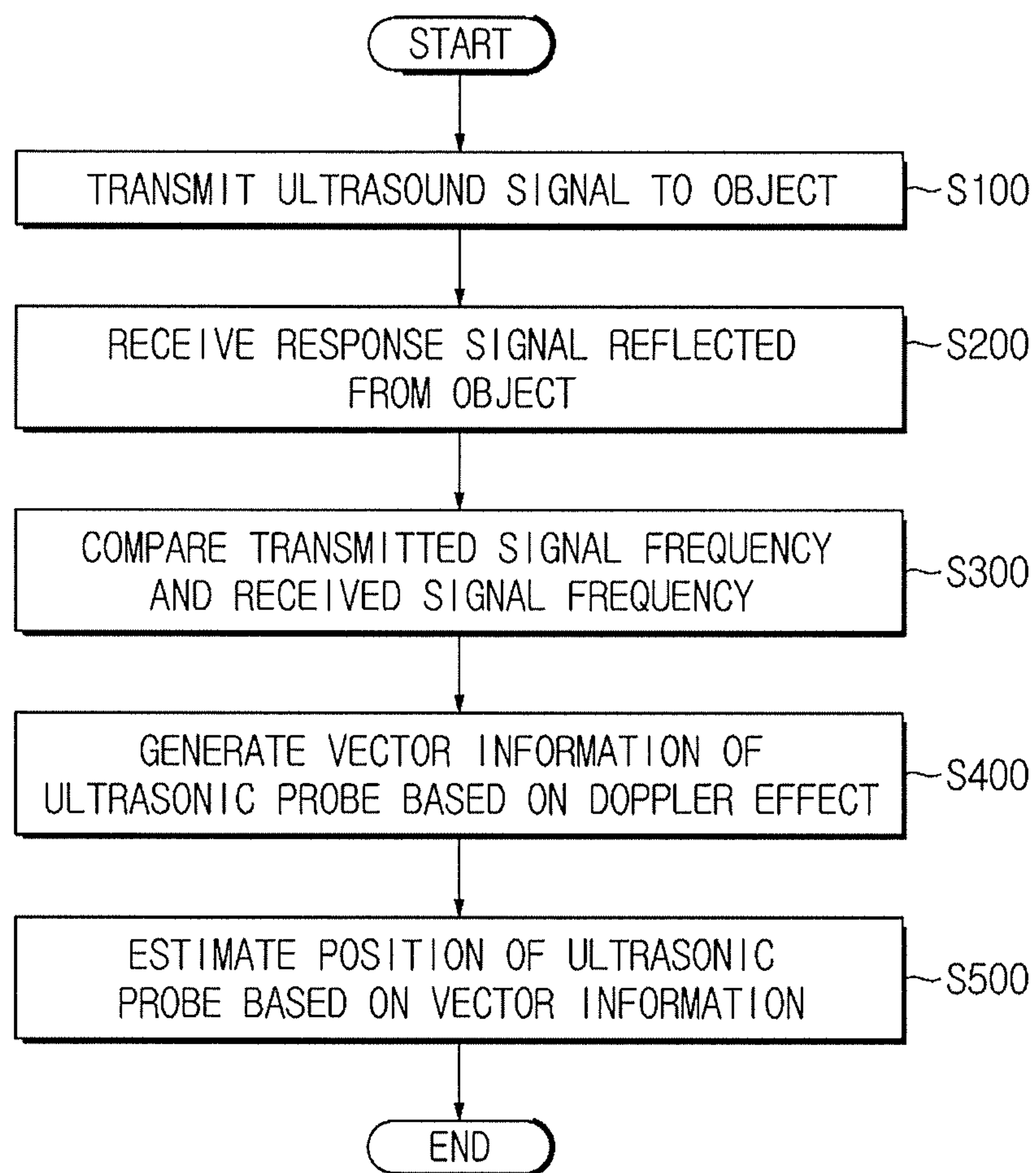
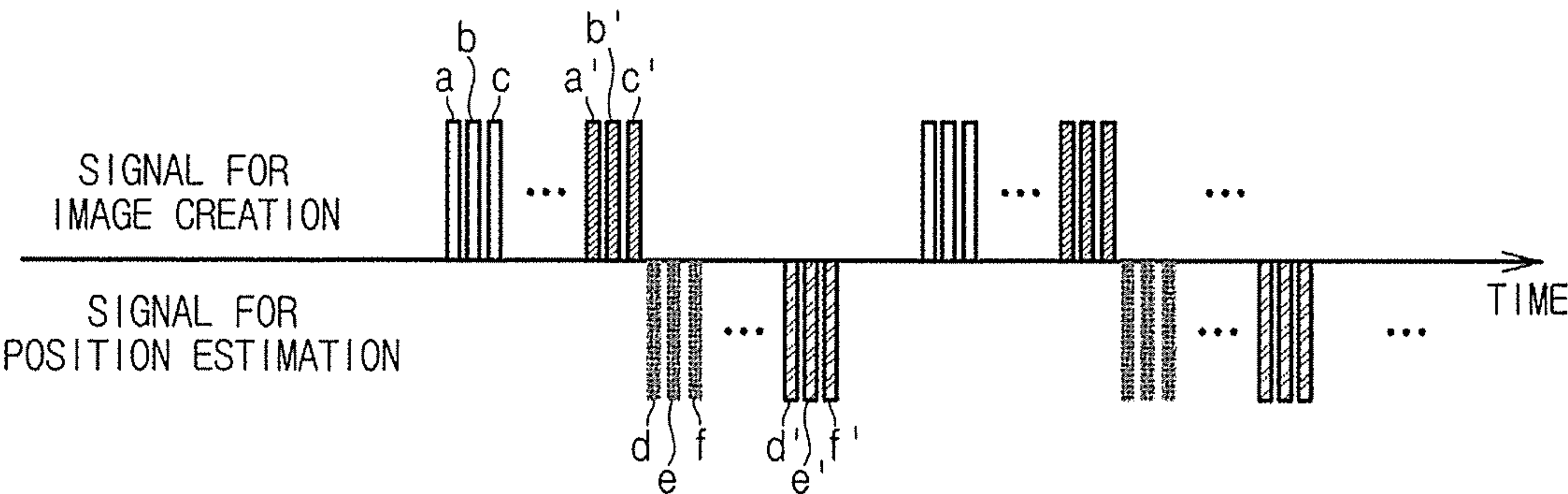
**FIG. 4**

FIG. 5





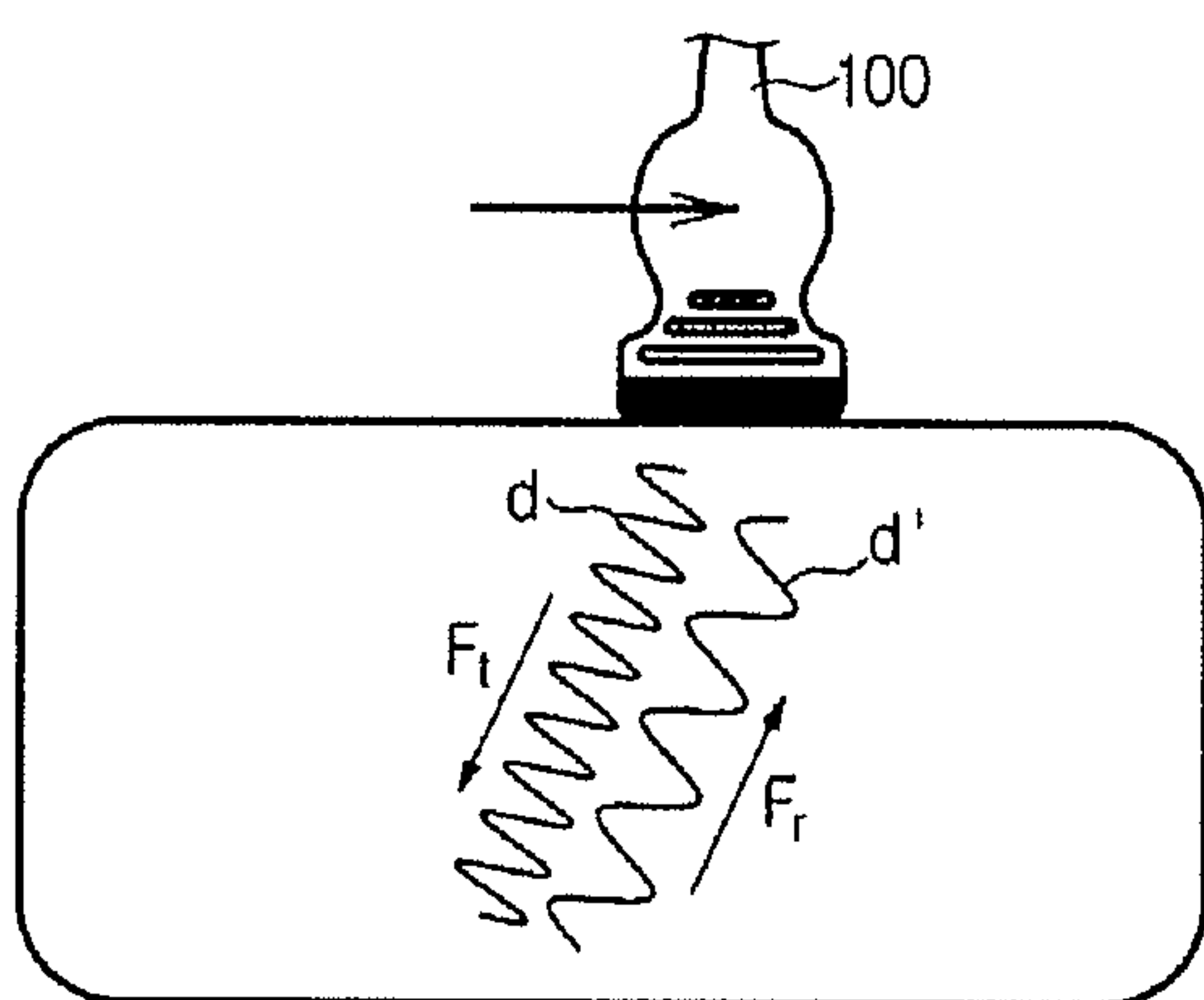


FIG. 6A

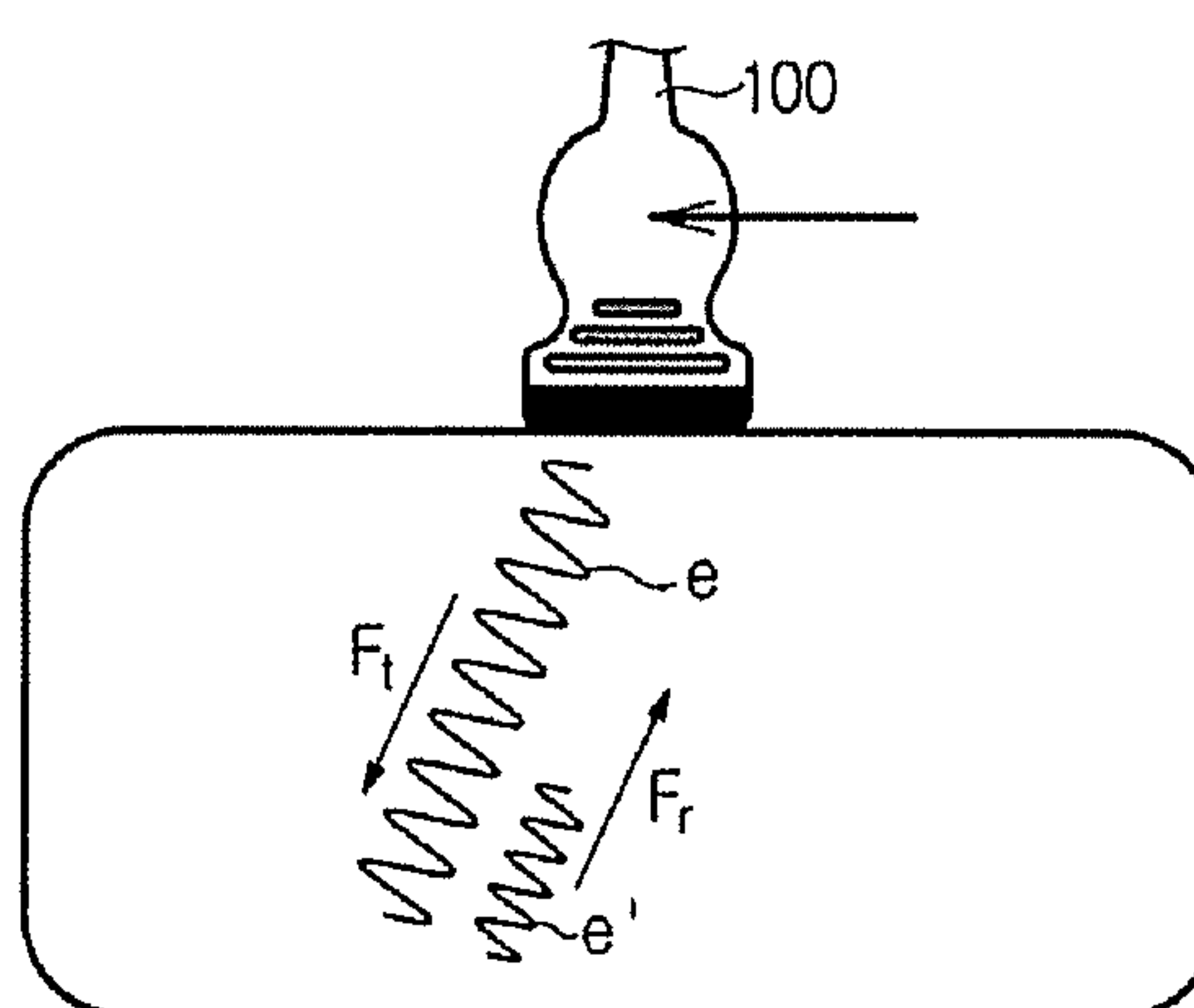


FIG. 6B

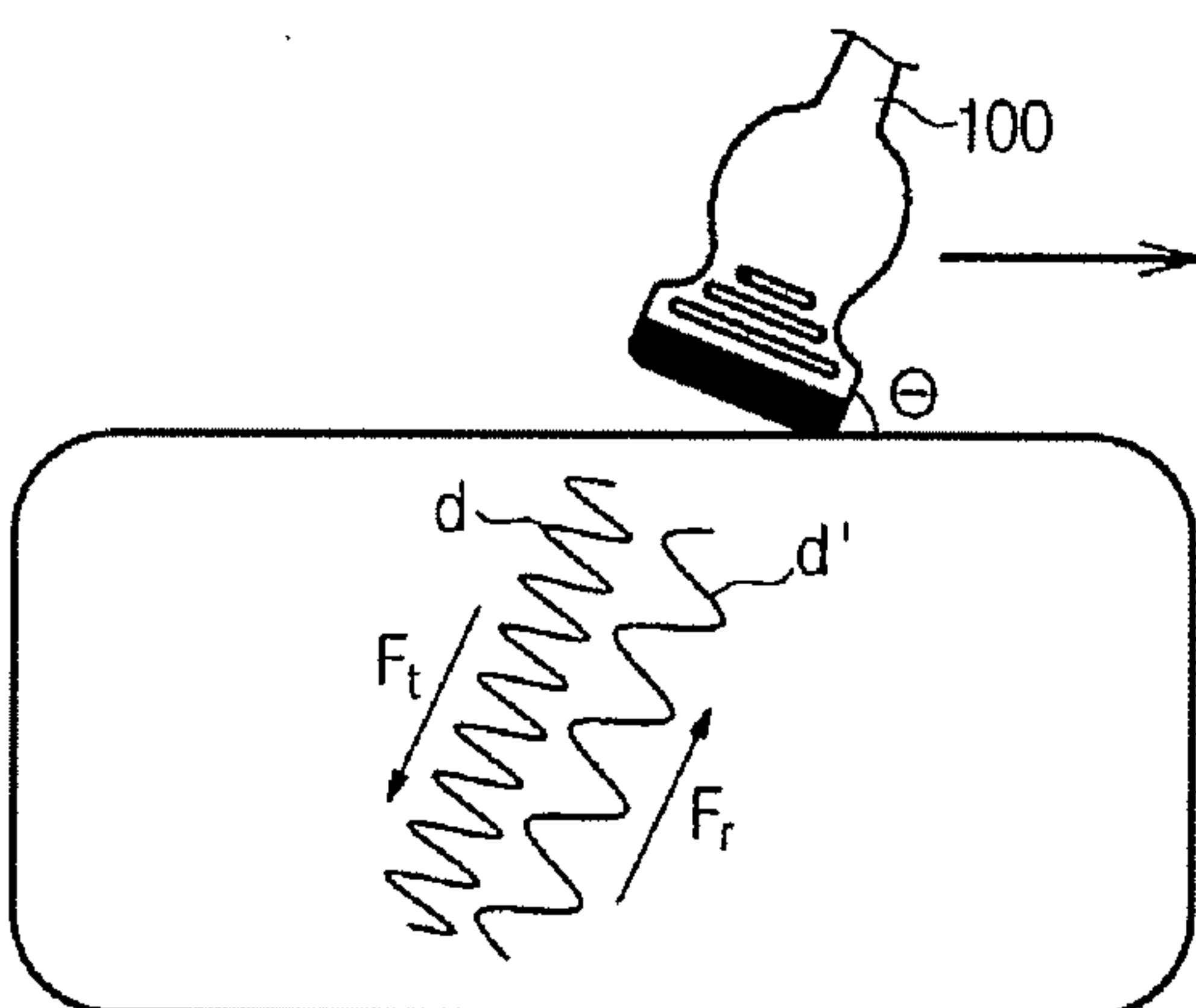


FIG. 6C

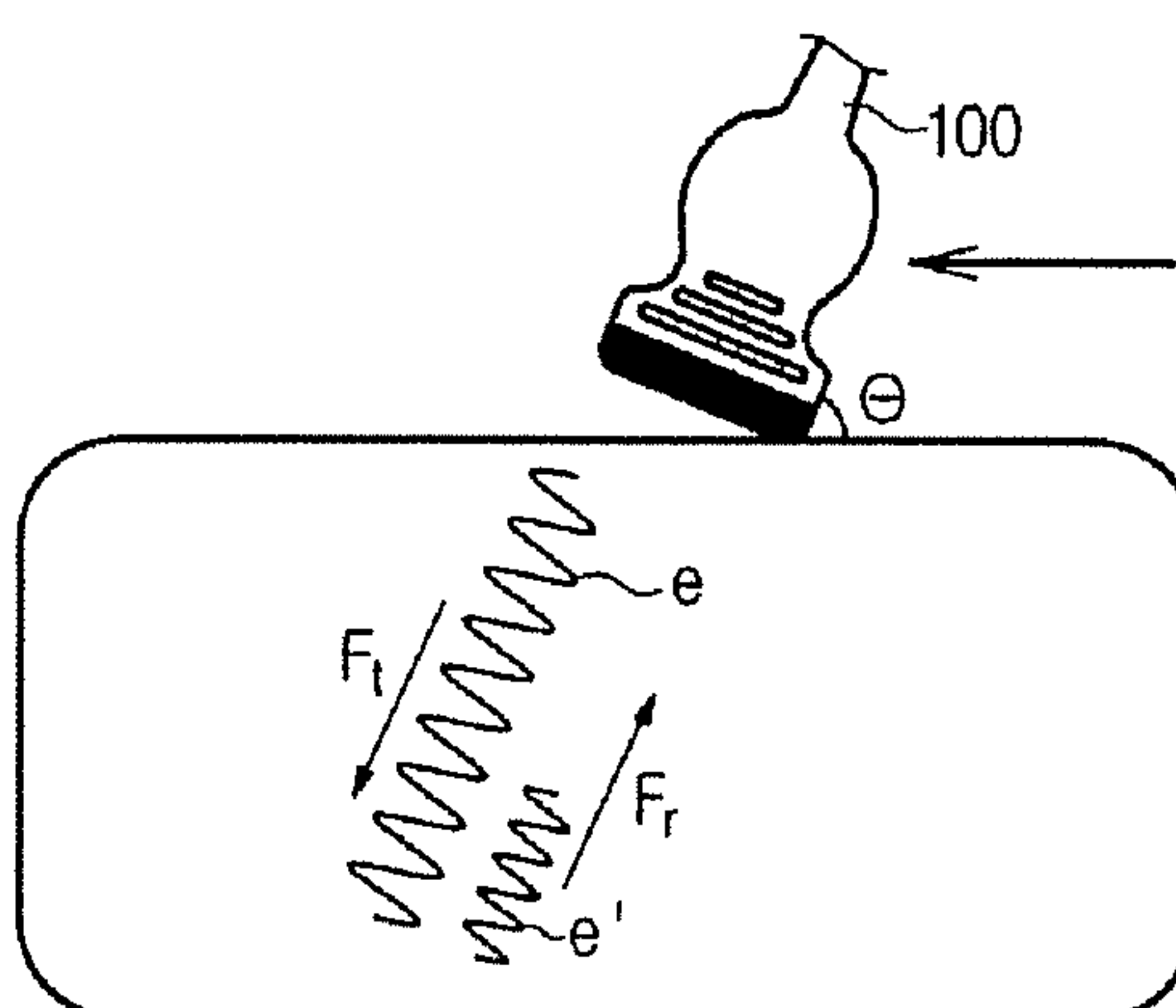


FIG. 6D

[DOPPLER EFFECT OCCURRING FROM PROBE MOTION]

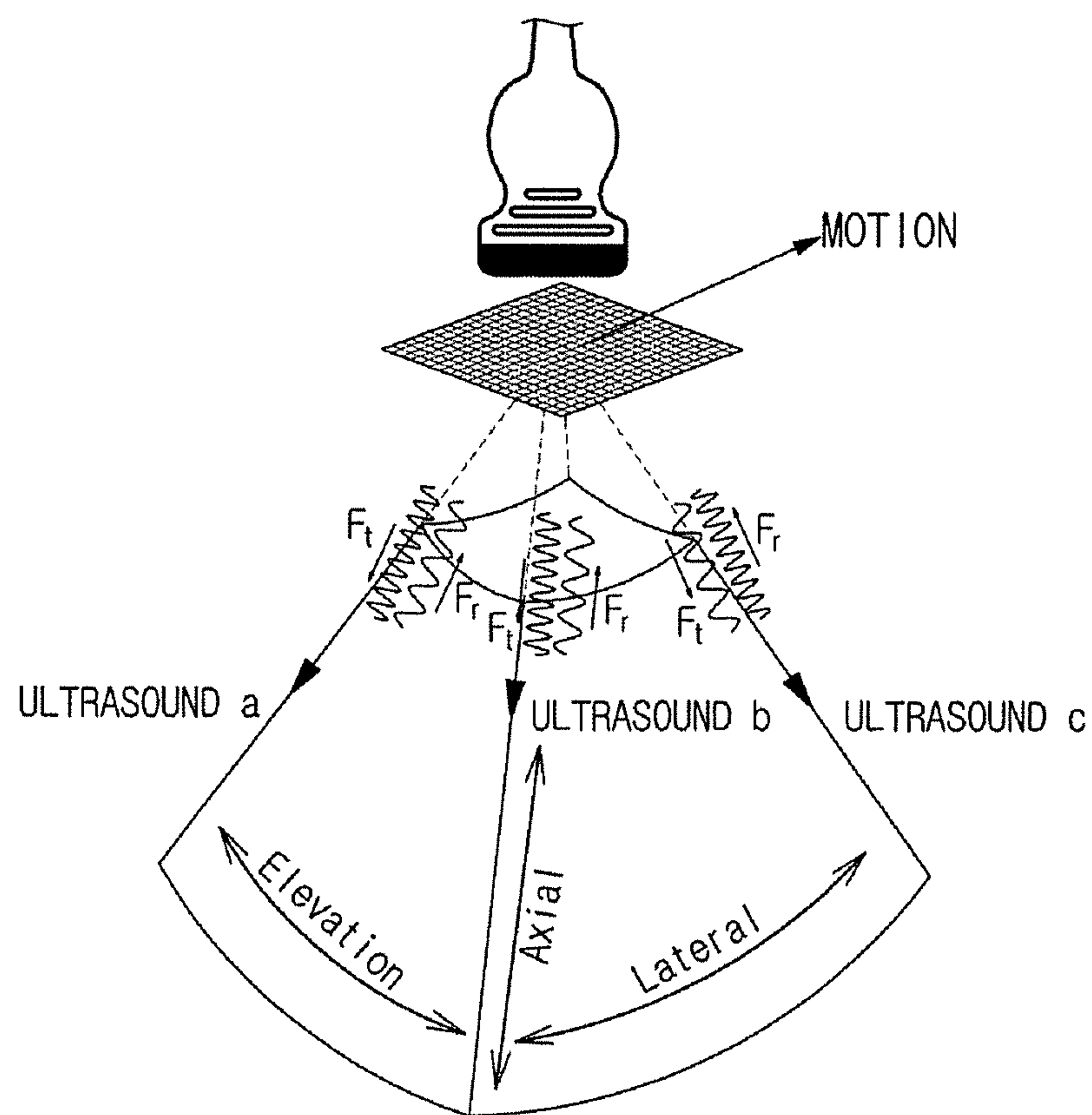


FIG. 7A

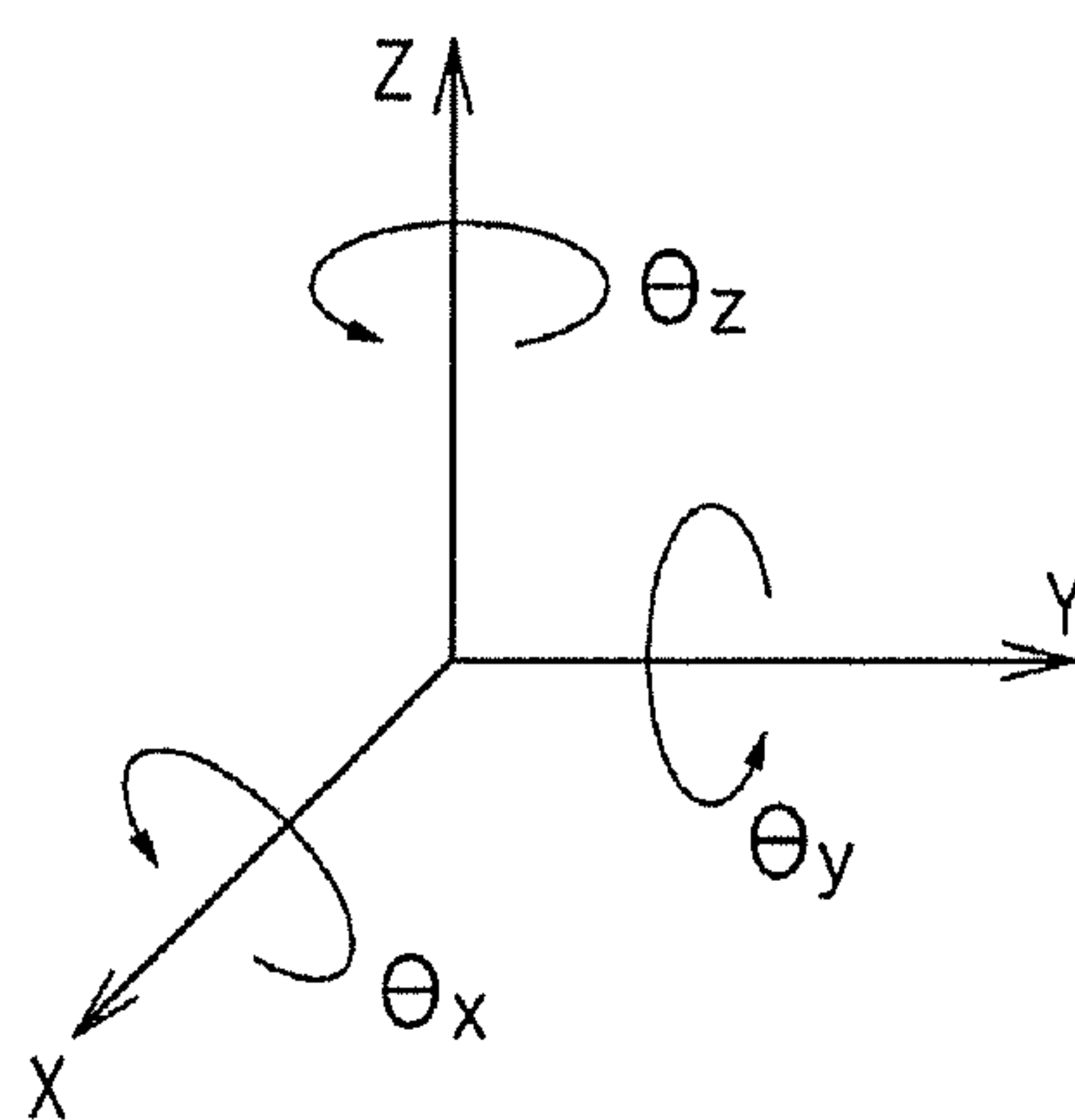
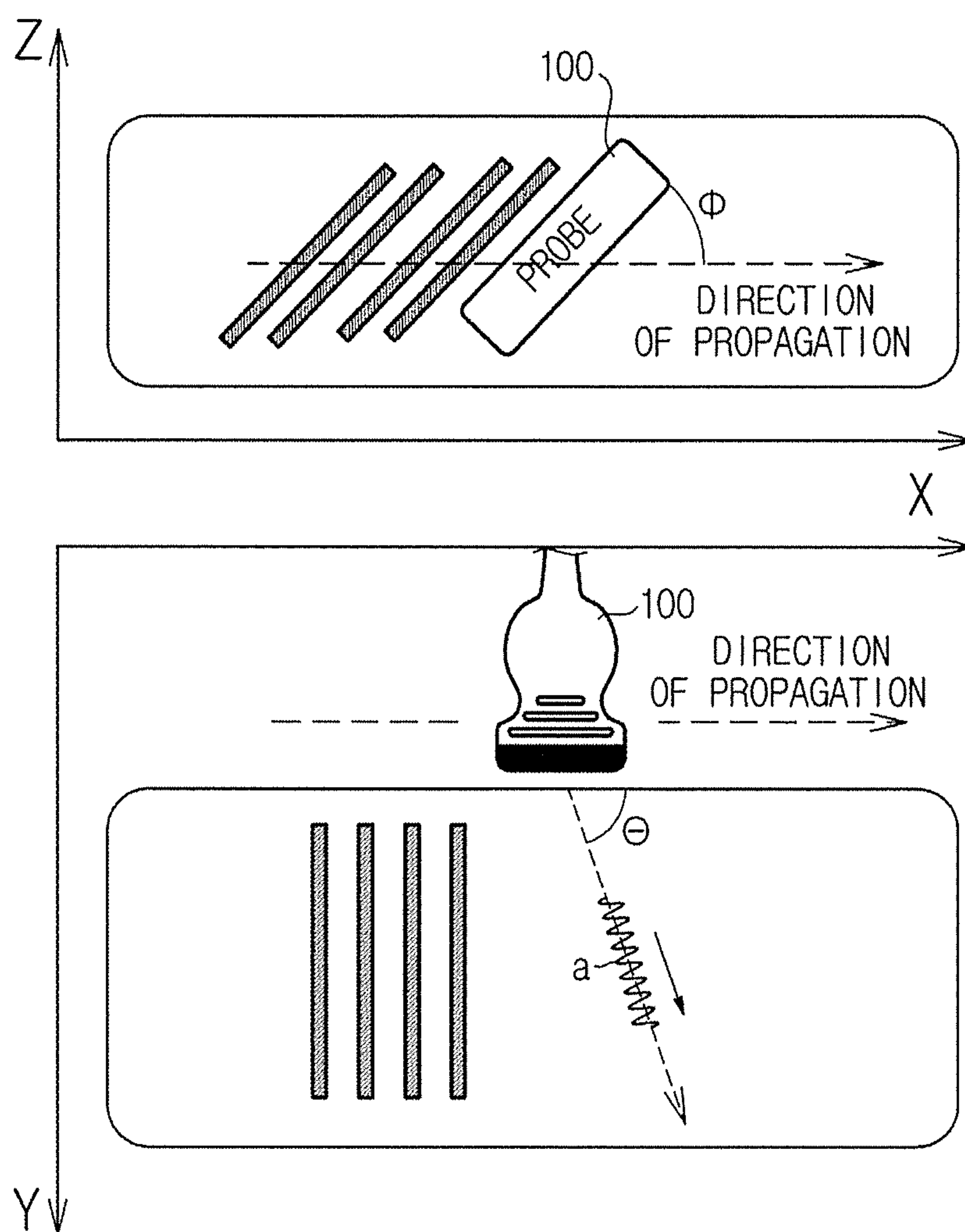


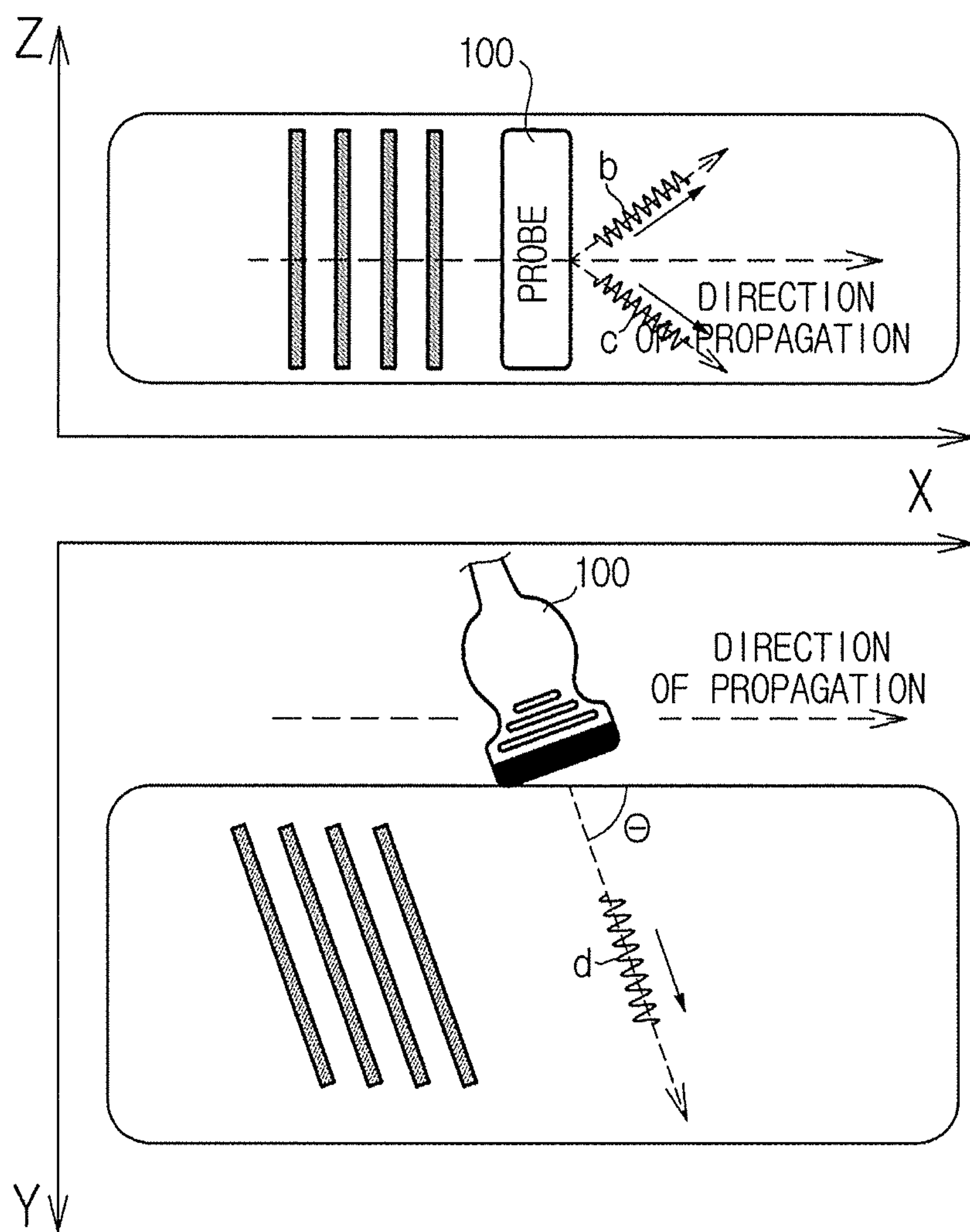
FIG. 7B

[DOPPLER EFFECT OCCURRING FROM MOTION OF 2D ARRAY PROBE]

**FIG. 8A**

[METHOD FOR CREATING VOLUME ULTRASOUND IMAGE USING 1D ARRAY PROBE]

**FIG. 8B**



[METHOD FOR CREATING VOLUME ULTRASOUND IMAGE USING 1D ARRAY PROBE]



FIG. 9A

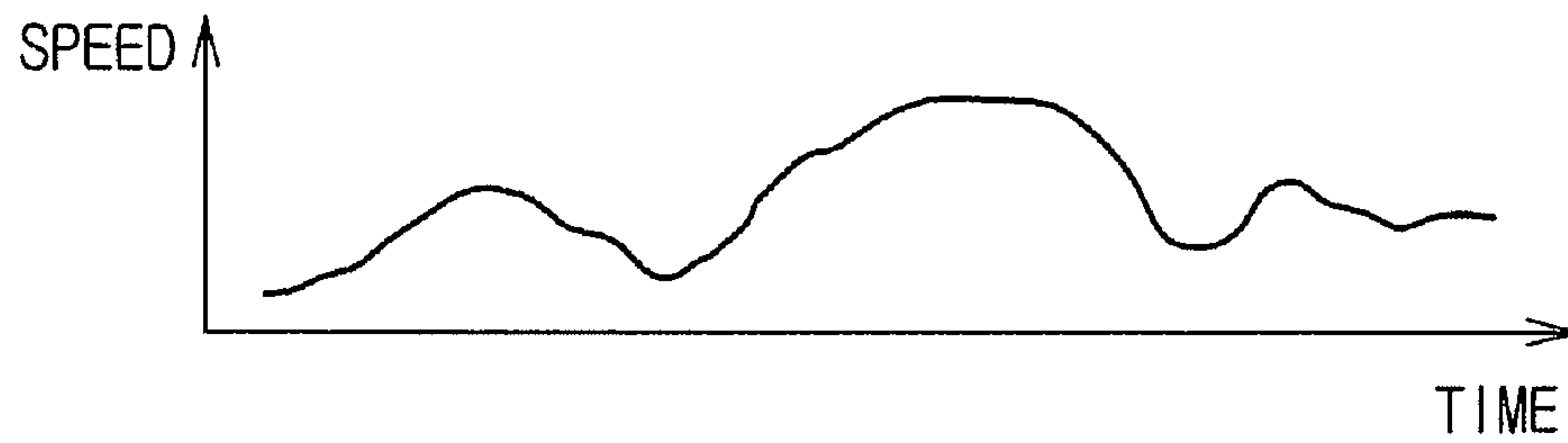


FIG. 9B

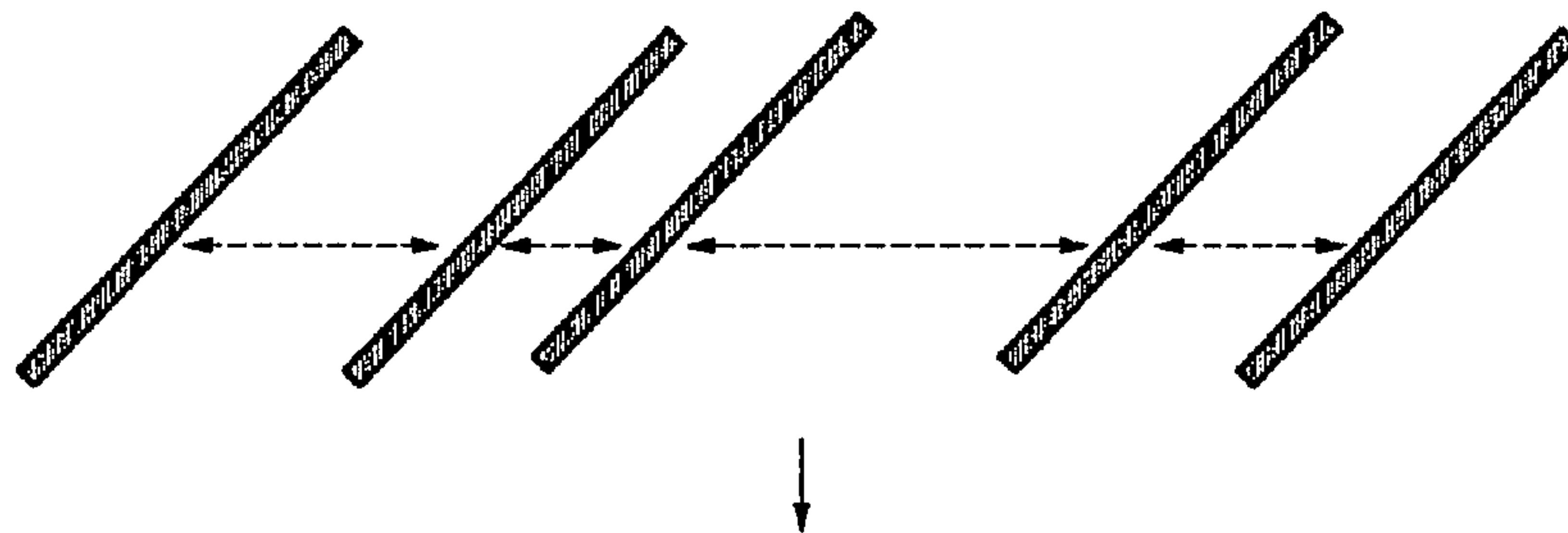
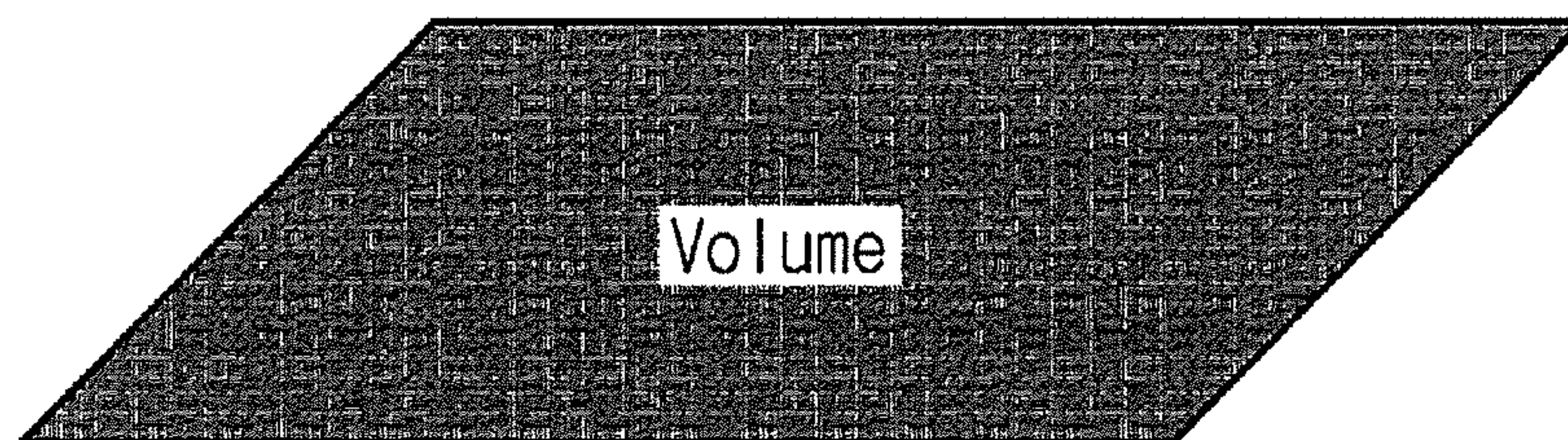
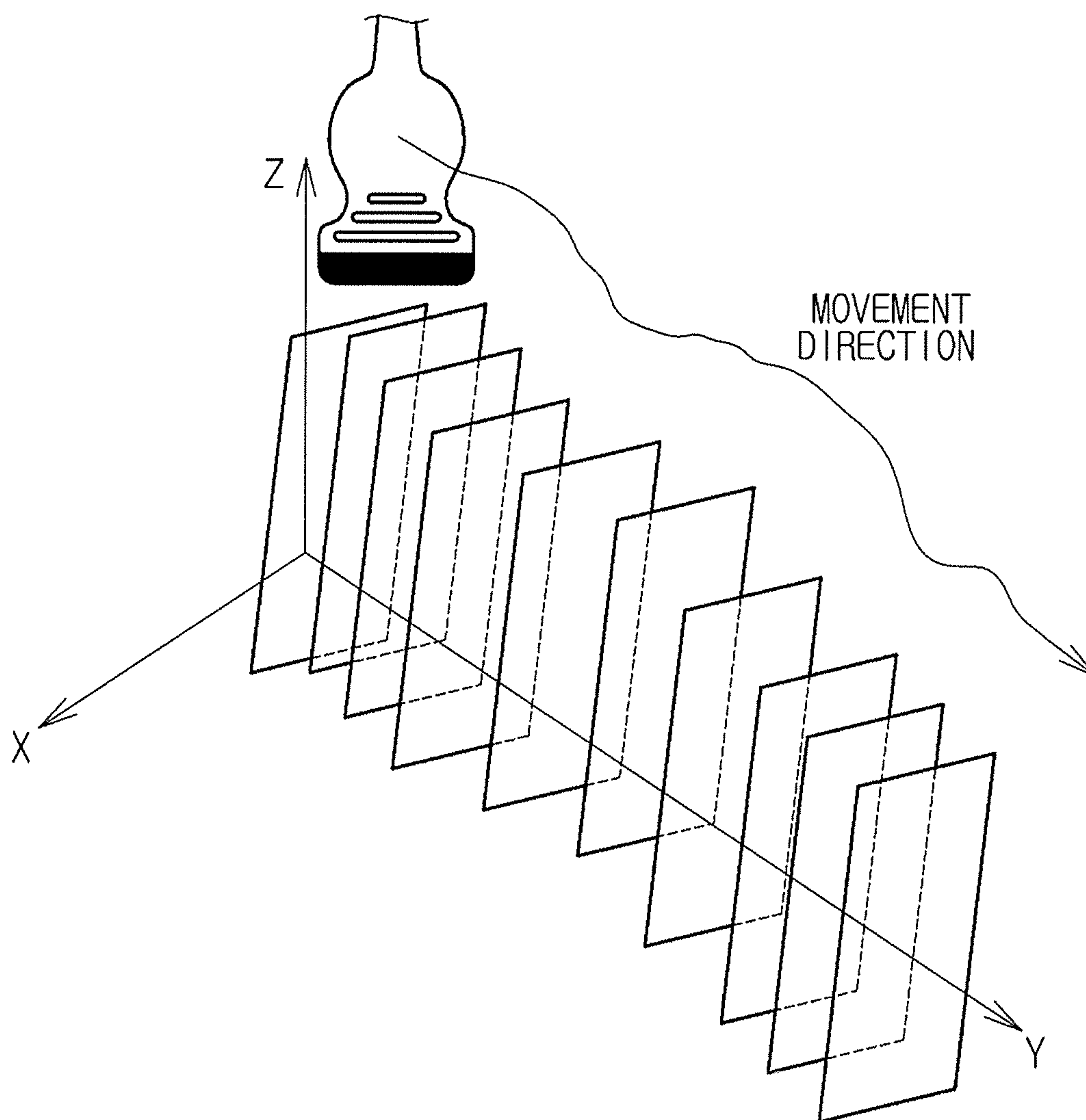


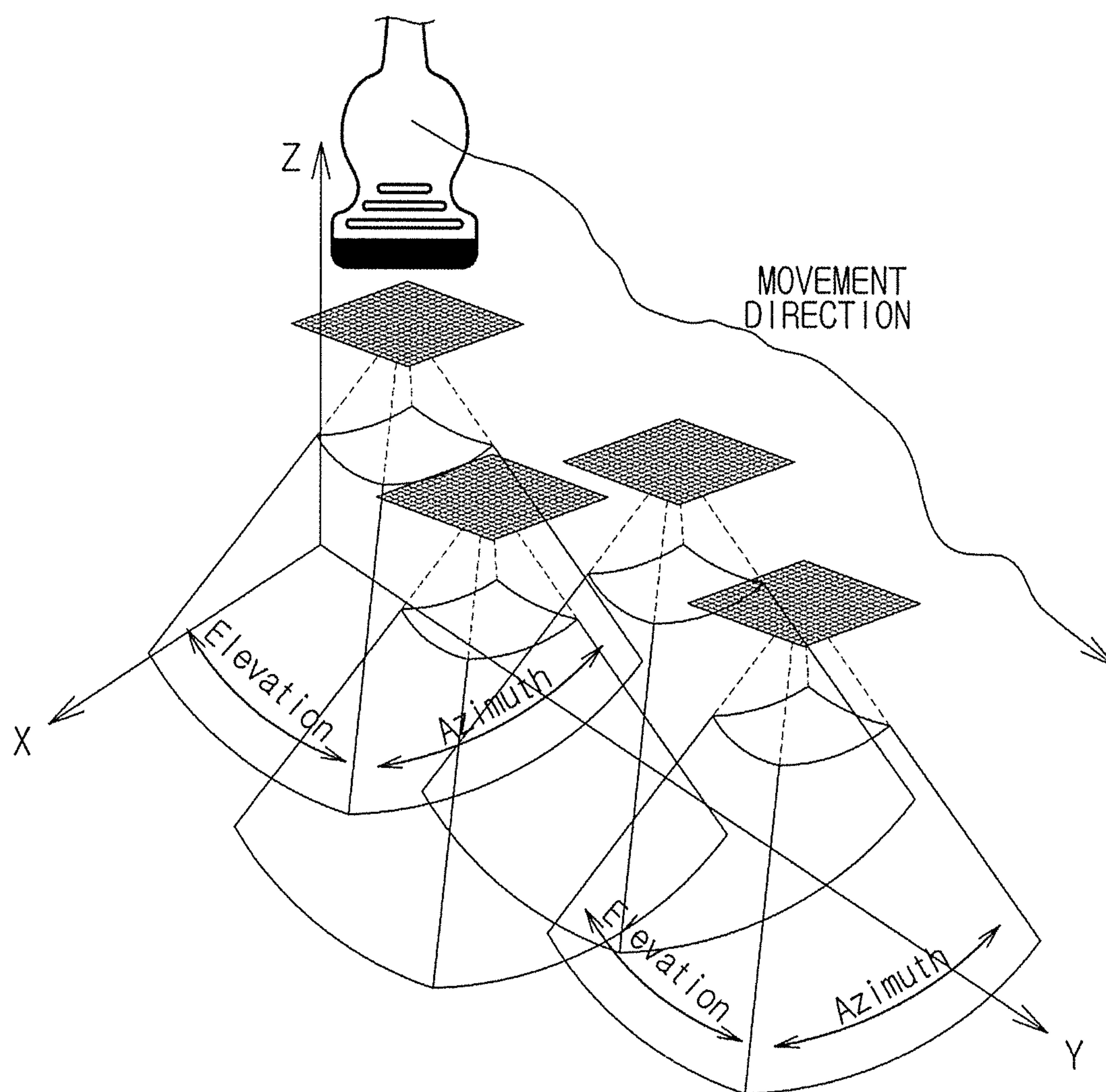
FIG. 9C



[METHOD FOR CREATING ULTRASOUND IMAGE USING 1D ARRAY PROBE]

**FIG. 10**

[METHOD FOR CREATING ULTRASOUND IMAGE USING 2D ARRAY PROBE]

**FIG. 11**

[METHOD FOR CREATING ULTRASOUND IMAGE USING 2D ARRAY PROBE]

**FIG. 12A**

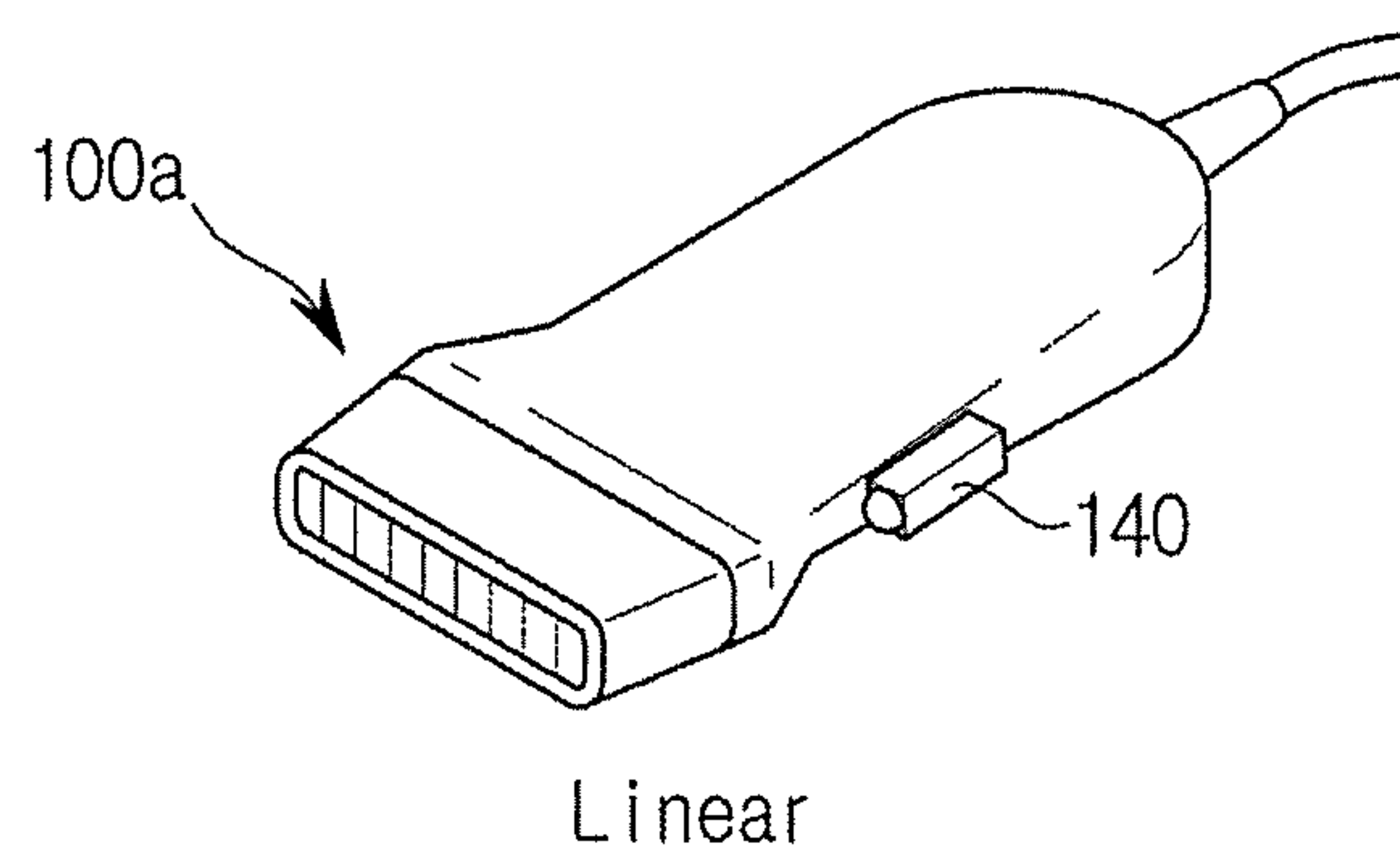
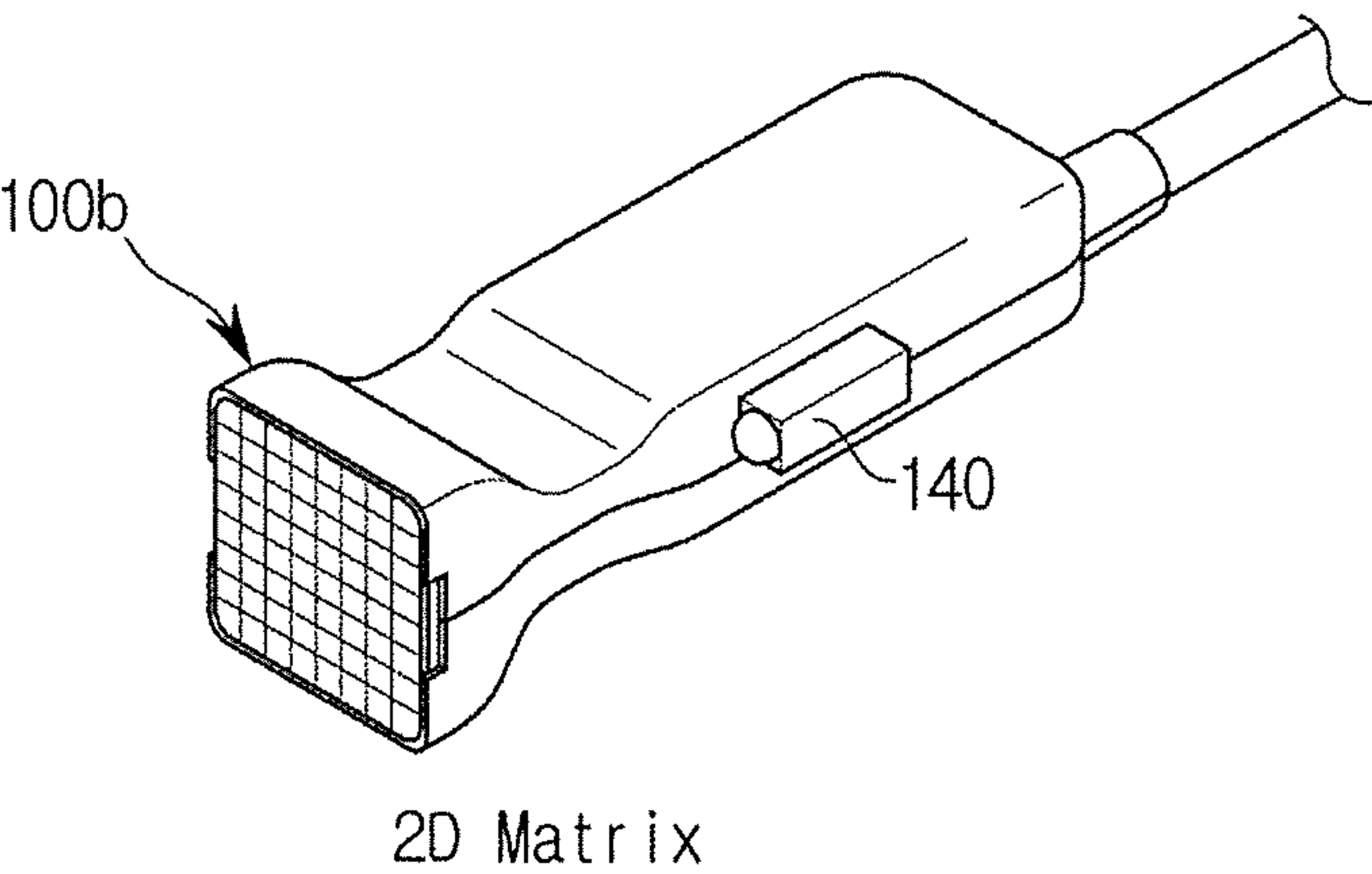




FIG. 12B



## 1

# ULTRASONIC DIAGNOSTIC APPARATUS FOR ESTIMATING POSITION OF PROBE AND METHOD FOR CONTROLLING THE SAME

## CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of Korean Patent Application No. 10-2017-0024035 filed on Feb. 23, 2017, the disclosure of which is incorporated herein by reference in its entirety.

## BACKGROUND

### 1. Field of the Invention

The present disclosure relates to an ultrasonic diagnostic apparatus and method for controlling the same, and more particularly, to a technology for estimating a current position of an ultrasonic probe using an ultrasound signal transmitted to an object and its response signal to create an ultrasound image.

### 2. Discussion of Related Art

Ultrasonic diagnostic equipment refers to a device that irradiates ultrasound signals toward a particular region of an object, receives ultrasound signals bouncing back from the object, and noninvasively obtains a cross-sectional tomogram of a soft tissue or an image of the blood flow using the information about the reflected ultrasound signal (or ultrasonic echo signal).

The ultrasonic diagnostic equipment has advantages of being relatively compact and inexpensive over the other imaging diagnostic equipments, such as the X-ray diagnostic device, the X-ray Computerized Tomography (CT) scanner, the Magnetic Resonance Image (MRI) device, the nuclear medicine diagnostic device, etc. The ultrasonic diagnostic equipment is able to obtain an image of an internal part of the object in real time, and has high stability because of no radiation exposure. Accordingly, in general, the ultrasonic diagnostic equipment is widely used for examination in cardiology, abdomen, urology, and women clinics.

The ultrasound diagnostic apparatus includes an ultrasonic probe for transmitting ultrasounds to an object and receiving a response signal bouncing back from the object to obtain an ultrasound image of the internal part of the object.

The ultrasonic probe includes a piezo-electric layer having a piezo-electric material therein to make conversions between an electric signal and an acoustic signal while vibrating, a matching layer enabling an ultrasound produced in the piezo-electric layer to be effectively delivered to the object by reducing a difference in acoustic impedance between the piezo-electric layer and the object, a lens having an ultrasound propagating forward from the piezo-electric layer focused at a particular point, and a sound-absorbing layer for blocking the ultrasound from propagating backward from the piezo-electric layer to prevent image distortion.

As for a method for creating an ultrasound image, a technology to estimate a current position of the ultrasound is required. For the conventional ultrasonic diagnostic equipment, there is a technology to estimate a position of the ultrasonic probe with a separate position sensor, a guide, or other components attached to the ultrasonic probe.

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In the case of the conventional technology, however, attaching the separate device to the ultrasonic probe to estimate the position of the ultrasonic probe increases the costs and has difficulty in creating images if the ultrasonic probe is a one dimensional (1D) array probe.

## SUMMARY OF THE INVENTION

To solve the aforementioned problem, the present disclosure provides more economical and more efficient ultrasonic diagnostic apparatus and method for controlling the same, by estimating the position of the ultrasonic probe using an ultrasound signal to be transmitted for creation of an ultrasound image without having an extra sensor attached thereto.

In accordance with an aspect of the present disclosure, there is provided an ultrasonic diagnostic apparatus comprising an ultrasonic probe configured to transmit an ultrasound signal to an object and receive a response signal reflected from the object, an image generator configured to create an ultrasound image of the object based on a first ultrasound signal and a first response signal and a controller configured to control transmission order and transmission intervals of the ultrasound signal and estimate a position of the ultrasonic probe based on a second ultrasound signal and a second response signal.

The controller may transmit the first ultrasound signal and the second ultrasound signal at different times.

The controller may estimate a position of the ultrasonic probe based on a change in frequency between the second ultrasound signal and the second response signal.

The controller may estimate a relative speed of the ultrasonic probe based on a change in frequency between the second ultrasound signal and the second response signal, and estimate a position of the ultrasonic probe based on the relative speed.

The controller may estimate a position of the ultrasonic probe based on the Doppler effect occurring between the second ultrasound signal and the second response signal.

The controller may create vector information of the ultrasonic probe based on the second ultrasound signal and the second response signal, and estimate a position of the ultrasonic probe based on the vector information.

The first and second ultrasound signals may include at least one of a brightness mode (B mode) image signal, a Doppler image signal, and a three dimensional (3D) image signal.

The controller may estimate a position of the ultrasonic probe based on an angle formed between the ultrasonic probe and the object and an angle of transmission of the second ultrasound signal.

The ultrasonic diagnostic apparatus may further include a first adjuster configured to adjust an angle formed between the ultrasonic probe and the object.

The ultrasonic diagnostic apparatus may further include a second adjuster configured to adjust an angle of transmission of the ultrasound signal.

The ultrasonic diagnostic apparatus may further include a sensor configured to detect operation information about the ultrasonic probe, wherein the controller may estimate a position of the ultrasonic probe based on the operation information.

The sensor may include at least one of a position sensor, an angle sensor, a gyro sensor, an acceleration sensor, an acoustic sensor, a photo sensor, and a magnetic sensor.



## 3

The ultrasonic probe may include a one dimensional (1D) array ultrasonic probe or a two dimensional (2D) ultrasonic probe.

The second ultrasound signal may include a plurality of second ultrasound signals with different angles, and the controller may estimate a position of the ultrasonic probe based on the plurality of second ultrasound signals and a plurality of second response signals reflected from the object.

The ultrasonic diagnostic apparatus may further include a volume image generator configured to create a volume image or panoramic image of the object based on the estimated position of the ultrasonic probe and the ultrasound image.

In accordance with another of the present disclosure, there is provided a method for controlling an ultrasonic diagnostic apparatus, the method may include transmitting an ultrasound signal to an object and receiving a response signal reflected from the object, creating an ultrasound image of the object based on a first ultrasound signal and a first response signal and estimating a position of the ultrasonic probe based on a second ultrasound signal and a second response signal.

The transmitting of an ultrasound signal to an object may include transmitting the first ultrasound signal and the second ultrasound signal at different times.

The estimating of a position of the ultrasonic probe may include estimating a relative speed of the ultrasonic probe based on a change in frequency between the second ultrasound signal and the second response signal, and estimating a position of the ultrasonic probe based on the relative speed.

The estimating of a position of the ultrasonic probe may include estimating a position of the ultrasonic probe based on the Doppler effect occurring between the second ultrasound signal and the second response signal.

The estimating of a position of the ultrasonic probe may include estimating a position of the ultrasonic probe based on an angle formed between the ultrasonic probe and the object and an angle of transmission of the second ultrasound signal.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present disclosure will become more apparent to those of ordinary skill in the art by describing in detail exemplary embodiments thereof with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of the appearance of an ultrasonic diagnostic apparatus, according to an embodiment of the present disclosure;

FIG. 2 is a block diagram of the internal configuration of an ultrasonic diagnostic apparatus, according to an embodiment of the present disclosure;

FIG. 3 is a perspective view of the appearance of various types of ultrasonic probes, according to an embodiment of the present disclosure;

FIG. 4 is a flowchart illustrating operation of an ultrasonic diagnostic apparatus, according to an embodiment of the present disclosure;

FIG. 5 shows transmission order and transmission scheme of ultrasound signals, according to an embodiment of the present disclosure;

FIGS. 6A-6D show the Doppler effect from the use of one dimensional (1D) array ultrasounds, according to an embodiment of the present disclosure;

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FIGS. 7A and 7B show the Doppler effect from the use of two dimensional (2D) array ultrasounds, according to an embodiment of the present disclosure;

FIGS. 8, and 9A-9C show a method for creating an ultrasound image using a 1D array ultrasonic probe, according to an embodiment of the present disclosure;

FIGS. 10 and 11 show a method for creating an ultrasound image using a 2D array ultrasonic probe, according to an embodiment of the present disclosure; and

FIG. 12 shows sensor-equipped ultrasonic probes, according to an embodiment of the present disclosure.

## DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Embodiments and features as described and illustrated in the present disclosure are only preferred examples, and various modifications thereof may also fall within the scope of the disclosure.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to limit the present disclosure. It is to be understood that the singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise.

It will be further understood that the terms “include”, “comprise” and/or “have” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

It will be understood that, although the terms first, second, third, etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms.

Embodiments of the present disclosure will now be described in detail with reference to accompanying drawings to be readily practiced by an ordinary skill in the art.

FIG. 1 is a perspective view of an ultrasonic diagnostic apparatus 300 with an ultrasonic probe 100, according to an embodiment of the present disclosure, FIG. 2 is a block diagram for explaining elements of the ultrasonic diagnostic apparatus 300, and FIG. 3 shows different types of ultrasonic probes 100 classified by the arrangement of transducers of the ultrasonic probe 100.

Referring to FIGS. 1 and 2, the ultrasonic diagnostic apparatus 300 may include a main body 200, an input 290 for receiving instructions from the user to control the ultrasonic diagnostic apparatus 300, and a display 280 for outputting information received from the input 290 and the main body 200.

Specifically, the main body 200 may control general operation of the ultrasonic diagnostic apparatus 300, and accordingly, may be equipped with various parts to control overall operation of the ultrasonic probe 100 or the main body 200. The main body 200 and the ultrasonic probe 100 may exchange data using a cable 93 or a wireless communication module.

Furthermore, the ultrasound probe 100 and the main body 200 may be connected to be able to communicate with each other using the connection cable 93, as shown in FIG. 1. An electric signal output from the ultrasonic probe 100 may be sent to the main body 200 through the connection cable 93. A control command created by the main body 200 may also be sent to the ultrasonic probe 100 through the connection cable 93.



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One end of the connection cable **93** may be attached to a connector **94**, which may be connected to and disconnected from a port **95** located on an outer case **201** of the main body **200**. While the connector **94** is connected to the port **95**, the ultrasonic probe **100** and the main body **200** may be communicatively connected.

On a side of the main body **200**, a probe holder **292** may be arranged to hold the ultrasonic probe **100**. The probe holder **292** may be provided as many as the number of the ultrasonic probes **100**, and detachably attached to the main body **200**. When not using the ultrasonic probe **100**, the user may hang the ultrasonic probe **100** on the probe holder **293**.

Furthermore, the main body **200** may receive an electric signal output from the ultrasonic probe **100** over a wireless communication network, and send an electric signal generated by the main body **200** to the ultrasonic probe **100**. In this case, the ultrasonic probe **100** and the main body **200** may each have a wireless communication module including an antenna and a wireless communication chip.

The wireless communication module may be a short-range communication module using at least one of Bluetooth, Bluetooth low energy, infrared data association (IrDA), wireless fidelity (Wi-Fi), Wi-Fi Direct, Ultra-Wideband (UWB), and Near Field Communication (NFC), or a radio communication module supporting ITU-authorized 3GPP family, 3GPP2 family, or IEEE family.

The main body **200** may exchange data with a hospital server or another medical equipment in the hospital connected through the Picture Archiving and Communication System (PACS) through the communication unit. Furthermore, the main body **200** may exchange data according to the Digital Imaging and Communications in Medicine (DICOM) standard. However, it is not limited thereto.

The display **280** may be combined with the main body **200** and may output various kinds of information received from the main body **200**.

Specifically, the display **280** may display an ultrasound image of a target part inside an object. The ultrasound image displayed on the display **280** may be a two dimensional (2D) or three dimensional (3D) ultrasound image, or a Doppler image, and various ultrasound images may be displayed according to operating modes of the ultrasonic diagnostic apparatus **300**.

In an embodiment, the ultrasound image may include an Amplitude mode (A-mode) image, Brightness Mode (B-mode) image, Motion mode (M-mode) image, and further include a Color mode (C-mode) image and Doppler mode (D-mode) image.

An A-mode image refers to an ultrasound image representing an amplitude of an ultrasound signal corresponding to an echo ultrasound signal; a B-mode image refers to an ultrasound image representing a magnitude of an ultrasound signal corresponding to an echo ultrasound signal by a brightness level; and an M-mode image refers to an ultrasound image representing movements of the object over time at a particular position. A D-mode image refers to an ultrasound image representing a moving object in waveforms by means of the Doppler effect, and a C-mode image refers to an ultrasound image representing a moving object in a color spectrum.

Accordingly, the display **280** may be implemented in various well-known methods, with Cathode Ray Tube (CRT), Liquid Crystal Display (LCD), Light Emitting Diodes (LEDs), Plasma Display Panel (PDP), Organic Light Emitting Diodes (OLEDs), etc. The input **290** may be implemented in various ways, e.g., with a keyboard, a foot switch, or a foot pedal.

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For example, the keyboard may be implemented in hardware. The keyboard may include at least one of switches, keys, a joy stick, and a trackball, or may be implemented in software such as a graphic user interface (GUI). In this case, the keyboard may be displayed by the main display **280**.

In a case that the display **280** is implemented in a type of touch screen, the display **280** may serve as the input unit **290** as well. The main unit **200** may receive various commands from the user through at least one of the display **280** and the input unit **290**. In an embodiment, a third display **291** shown in FIG. **1** may have both display and input functions.

Given that the display **280** and the input **290** receive or send information to the user, the display **280** and the input **290** may be collectively defined as an input/output unit **270**.

The main body **200** of the ultrasonic diagnostic apparatus **300** has thus far been examined in connection with FIG. **1**. Configurations and types of the ultrasonic probe **100** will now be described with reference to FIGS. **2** and **3**.

Referring to FIG. **2**, the ultrasonic probe **100** may include an ultrasonic transceiver **110** for generating or receiving ultrasounds, a first processor **130** electrically connected to the ultrasonic transceiver **110** for controlling operation of the ultrasonic transceiver **110** or performing signal processing with an electric signal output from an ultrasonic element, a sensor **140** for detecting information about operation of the ultrasonic probe **100**, a first angle adjuster **151** for adjusting an angle formed between the ultrasonic probe **100** and an object **99**, and a second angle adjuster **152** for adjusting an angle of transmission of an ultrasound signal.

The ultrasonic transceiver **110** may include ultrasonic transducers for generating an ultrasound or an electric signal corresponding to an ultrasound. Specifically, the ultrasonic transducer may generate an ultrasound by converting alternate current (AC) energy with a certain frequency into mechanical vibrations with the same frequency, or convert mechanical vibrations with a certain frequency caused by a received ultrasound to AC energy. That is, the ultrasonic transducer may generate an ultrasound or may output an electric signal corresponding to an ultrasound.

Referring to FIG. **2**, the ultrasonic transceiver **110** may include an ultrasonic transmitter **110a** and an ultrasonic receiver **110b**.

The ultrasonic transmitter **110a** may generate an ultrasound with a frequency corresponding to a frequency of a pulse signal sent from the first processor **130** or the second processor **220**. The ultrasound may be irradiated to a target portion **98** of the object **99**.

The ultrasonic receiver **110b** may receive an ultrasound bouncing back from the target portion **98** of the object **99** or an ultrasound generated at the target portion **98** from e.g., a laser, and convert the received signal to an ultrasound signal. The ultrasonic receiver **110b** may include a plurality of ultrasonic transducers, each of which outputs an ultrasound signal, and may thus output ultrasound signals of a plurality of channels.

Furthermore, the ultrasonic receiver **110b** may be installed on one side of an acoustic absorber **120**, and the acoustic absorber **120** may have a first connector **121** for the ultrasonic transceiver **110**.

In an embodiment, the first connector **121** may be installed in the acoustic absorber **120** by passing through the acoustic absorber **120**, in which case the first connector **121** may be installed by even penetrating the other side of the acoustic absorber **120**.

The first processor **130** may generate and output an electric signal to control the ultrasonic transceiver **110**, or



use an ultrasound signal sent from the ultrasonic transceiver **110** to perform various kinds of signal processing.

The electric signal output from the first processor **130** may be sent to the ultrasonic transceiver **110**, e.g., the ultrasonic transmitter **110a**, through the first connector **121**. The ultrasonic transmitter **110a** may operate in response to the received electric signal.

In the embodiment of FIG. 2, the first processor **130** may include at least one of a pulser **131**, an amplifier (AMP) **132**, an analog-digital converter (ADC) **133**, and a beamformer (or B.F.) **134**.

The pulser **131** may generate voltage with a certain frequency to operate the ultrasonic transceiver **110** and send the voltage to the ultrasonic transceiver **110**. The ultrasonic transceiver **110** may generate an ultrasound by vibrating according to the amplitude and frequency of the voltage output from the pulser **131**.

A frequency and intensity of the ultrasound generated by the ultrasonic transceiver **110** may be determined based on the amplitude and frequency of the voltage generated by the pulser **131**. The voltage output from the pulser **131** may be applied to the ultrasonic transceiver **110** at certain intervals, and accordingly, the ultrasound generated by the ultrasonic transceiver **110** may be focused at the target portion **98** or steered to a certain direction.

In some embodiments, the pulser **131** may be included in the second processor **221**. In this case, the first processor **130** may not include the pulser **131**.

The AMP **132** may amplify the ultrasound signal output from the ultrasonic receiver **110b** of the ultrasonic transceiver **110**. In some embodiments, the amplifier **132** may compensate for dynamic differences between ultrasound signals of the plurality of channels by differently amplifying the ultrasound signals of the plurality of channels output from the plurality of ultrasonic transceivers **110**.

The ADC **133** may convert an amplified analog ultrasound signals to a digital signal. The ADC **133** may sample the analog ultrasound signal at a predetermined sampling rate to output the digital signal.

The beamformer **134** may focus the ultrasound signals input on the plurality of channels into a beam. The beamformer **134** may focus the signals sent from the ultrasonic transceiver **110**, the AMP **132**, or the ADC **133** to produce a beamformed signal. The beamformer **134** may perform electronic beam scanning, steering, focusing and apodizing on the signals of the plurality of channels.

Furthermore, if the ultrasonic probe **100** is a wireless ultrasonic probe, it may be further equipped with a battery (not shown) to supply power to the ultrasonic probe **100**.

The sensor **140** is attached onto a side of the ultrasonic probe **100** to detect many different kinds of operation information of the ultrasonic probe **100**.

Specifically, the sensor **140** may include at least one of a position sensor, an angle sensor, a gyro sensor, an acceleration sensor, an acoustic sensor, a photo sensor, and a magnetic sensor, and the many different kinds of operation information of the ultrasonic probe **100** obtained from the enumerated sensors may be basic information for the controller **220** to estimate a position of the ultrasonic probe **100**.

The angle adjuster **150** may include a first angle adjuster **151** and a second angle adjuster **152**.

Specifically, the first angle adjuster **151** may adjust an angle formed between the ultrasonic probe **100** and the object **99**, and the second angle adjuster **152** may adjust an angle of transmission of an ultrasound transmitted from the ultrasonic transceiver **110**.

As will be described later in connection with FIG. 8, since the position of the ultrasonic probe **100** is estimated by compensation based on the angle formed between the ultrasonic probe **100** and the object **99** in the embodiment of the present disclosure, the first angle adjuster **151** may adjust the angle formed between the ultrasonic probe **100** and the object **99** and the second angle adjuster **152** may adjust the angle of an ultrasound signal to be transmitted by the ultrasonic transceiver **110** to the object **99**.

Furthermore, the first angle adjuster **151** may be further equipped with a fixer (not shown) to fix the ultrasonic probe **100** and the object **99** to form a constant angle.

As shown in FIG. 2, the main body **200** may include a signal processor **210**, an image generator **230**, a volume data generator **240**, a storage **250**, and a controller **220**.

The signal processor **210** may perform various signal processing on the beamformed signal. For example, the signal processor **210** may perform at least one of a filtering process, a detection process, and a compression process. The filtering process is a process to eliminate other signals than a signal in a particular bandwidth by applying a filter to the beamformed signal. The filtering process may include a harmonic imaging process to eliminate fundamental frequency components while passing harmonic signals. The detection process is a process to transform the voltage of an ultrasound signal from a radio frequency format to a video signal format. The compression process is a process to reduce the difference in amplitude between ultrasound signals. The image generator **230** may be omitted as needed.

The image generator **230** may convert a beamformed signal or a signal processed by the signal processor **210** to an ultrasound image in the format of a still image or moving image, and if needed, may process image processing on the still image or the moving image.

The image generator **230** may generate an ultrasound image using scan conversion. The ultrasound image may include an A mode image, a B mode image, an M mode image, a D mode image, or a 3D image. The ultrasound image may include the D image formed by using the Doppler effect.

The A mode ultrasound image refers to an ultrasound image obtained by imaging the intensity of reflection in amplitudes based on a distance or time between the target portion **98** and the ultrasonic probe **100**, and the B mode ultrasound image refers to an ultrasound image obtained by representing the intensity of the ultrasound by brightness. The M mode ultrasound image refers to an ultrasound image obtained by imaging an extent of change in motion of the object being imaged. The D image may include a blood-stream Doppler image (also referred to as a color Doppler image), a tissue Doppler image that represents movement of tissues, or a spectral Doppler image that represents the moving speed of the object in a waveform.

Accordingly, the B mode generator **231** may extract B mode components from ultrasound data and generate an ultrasound image by representing the intensity of the signal in brightness based on the extracted B mode components.

Similarly, the Doppler generator **232** may extract Doppler components from the ultrasound data, and may generate a D image that represents a motion of the object in colors or waveforms based on the Doppler components.

The image generator **230** may also correct the generated ultrasound image. For example, the image generator **230** may correct brightness, luminosity, sharpness, contrast, color or the like of an entire or a part of the ultrasound image in order for the user to clearly view tissues in the ultrasound



image. As needed, the image generator **230** may cancel noise in the ultrasound image or perform pixel interpolation.

The image generator **230** may send the generated or corrected ultrasound image to the storage **250**, or display the ultrasound image on the display **280**. The image generator **230** may also send the generated or corrected ultrasound image to the volume data generator **240** to obtain ultrasound volume data.

The volume data generator **240** may obtain ultrasound volume data representing a 3D volume based on the generated or corrected 2D ultrasound image.

The signal processor **210**, the image generator **230**, and the volume data generator **240** may be implemented by a central processing unit (CPU) or a graphic processing unit (GPU). The CPU or GPU may be implemented with at least one semiconductor chip and associated components.

The storage **250** may store various programs or data related to functions of the controller **220**, ultrasound images, and various kinds of information regarding the ultrasound images. The storage **250** may be implemented using a semiconductor storage device, a magnetic disk storage device, or a magnetic tape storage device.

The controller **220** may control overall operations of the ultrasound diagnostic apparatus **300** in accordance with commands from the user or predefined settings. For example, the controller **220** may generate a control command based on the frequency of an ultrasound to be irradiated, and send the control command to the pulser **131** of the first processor **13**, which may in turn, apply a voltage with a certain frequency to the ultrasonic transceiver **110** according to the control command. Accordingly, the ultrasonic transceiver **110** may be able to generate and irradiate an ultrasound with the certain frequency to the target portion **98** of the object **99**.

The controller **220** may include a read only memory (ROM) or random access memory (RAM) to assist in the second processor **221** and operation of the second processor **221**. The second processor **221** may be implemented by a CPU. The CPU may be implemented with one or more semiconductor chips and associated components.

FIG. **3** shows different types of ultrasonic probes **100** classified by the shape of the ultrasonic transceiver **110** of the ultrasonic probe **100**.

The ultrasonic probe **100a** shown in (a) of FIG. **3** is a linear probe, in which case, transducers are arranged in a straight line.

A probe shown in (b) of FIG. **3** is a 2D matrix array ultrasonic probe **100b**, which may provide a stereoscopic 360 degree image of the object, which is an ultrasonic diagnostic image.

However, the ultrasonic probe **100** is not limited thereto, and may be implemented in other forms than those shown in FIG. **3**, which are known to an ordinary skill in the art, such as a phased array probe, a 3D matrix probe, etc.

Meanwhile, three directions may be defined: axial direction A, lateral direction L, and elevation direction E, which are perpendicular to each other with respect to the probe **100**. Specifically, the axial direction A may be defined to be a direction in which an ultrasound signal is irradiated; the lateral direction L may be defined to be a direction in which the transducers are arranged, i.e., a direction of a row of the transducers; and the elevation direction E may be defined to be a direction perpendicular to the axial direction A and the lateral direction L.

External and internal configurations of the ultrasonic probe **100** and the ultrasonic diagnostic apparatus **300** have

thus far been described. Operations flows of the present disclosure will now be described.

FIG. **4** is a flowchart illustrating operation of an ultrasonic diagnostic apparatus, according to an embodiment of the present disclosure, FIG. **5** shows transmission order and transmission scheme of ultrasound signals, according to an embodiment of the present disclosure, FIGS. **6A-6D** show the Doppler effect from the use of 1D array ultrasounds, according to an embodiment of the present disclosure, and FIGS. **7A** and **7B** show the Doppler effect from the use of 2D array ultrasounds, according to an embodiment of the present disclosure.

Referring to FIG. **4**, the ultrasonic probe **100** of the ultrasonic diagnostic apparatus **300** transmits ultrasounds to the object and receives a response signal bouncing back from the object, **S100**, **S200**.

The ultrasonic transceiver **110** may transmit and receive ultrasound signals toward and from the object **99**, and the signals for transmission are of the same kind but may be differently used for their purposes.

For example, in order to generate an ultrasound image, the ultrasonic transceiver **110** may transmit an ultrasound signal for creation of an ultrasound image, and in order to estimate a position of the ultrasonic probe **100**, the ultrasonic transceiver **110** may transmit an ultrasound signal for estimation of a position to the object **99**.

In the following description, a signal to be transmitted by the ultrasonic transceiver **110** to the object **99** for creation of an ultrasound image will be called a first ultrasound signal, and the signal bouncing back from the object **99** will be called a first response signal; a signal to be transmitted by the ultrasonic transceiver **110** to the object **99** for estimation of a position of the ultrasonic probe **100** will be called a second ultrasound signal, and the signal bouncing back from the object **99** will be called a second response signal.

For example, to generate a B mode image, the ultrasonic transceiver **110** may generate a B mode transmission signal, transmit the first ultrasound signal obtained by converting the B mode transmission signal to an ultrasound signal to the object **99**, and receive the first response signal bouncing back from the object **99**, and based on which, the image generator **230** may generate a B mode image.

To generate a D image, the ultrasonic transceiver **110** may generate a D mode transmission signal, transmit the first ultrasound signal obtained by converting the D mode transmission signal to an ultrasound signal to the object **99**, and receive the first response signal bouncing back from the object **99**, and based on which the image generator **230** may generate a D image.

On the other hand, to estimate a position of the ultrasonic probe **100**, the ultrasonic transceiver **110** may transmit the second ultrasound signal for estimation of the position of the ultrasonic probe **100** to the object **99**, and receive the second response signal bouncing back from the object **99**, and the controller **220** may estimate the position of the ultrasonic probe **110** based on the second ultrasound signal and the second response signal.

FIG. **5** shows transmission and reception of the first ultrasound signal and first response signal and the second ultrasound signal and second response signal.

Referring to FIG. **5**, the ultrasonic transceiver **110** may transmit the first ultrasound signal (signals a, b, and c) for generation of an ultrasound image to the object **99** and receive the first response signal (signals a', b', and c') bouncing back from the object **99**, and based on which, the image generator **230** may generate an ultrasound image of the object **99**.



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Furthermore, the ultrasonic transceiver **110** may transmit the second ultrasound signal (signals d, e, and f) for estimation of a position of the ultrasonic probe **100** to the object **99** and receive the second response signal (signals d', e', and f) bouncing back from the object **99**, and the controller **220** may estimate the position of the ultrasonic probe **100** based on the second ultrasound signal and the second response signal.

However, since the ultrasonic transceiver **110** may not transmit multiple signals at the same time, the first ultrasound signal for generation of an ultrasound image and the second ultrasound signal for estimation of a position of the ultrasonic probe **100** may be transmitted and received at different times. The order and transmission intervals may be changed in various ways according to commands from the user or a use environment.

In the embodiment of the present disclosure, since the position of the ultrasonic probe **100** is estimated using an ultrasound signal to generate an image of the ultrasonic probe **100**, there is no need for an extra sensor, so the costs may be reduced.

The first and second ultrasound signals are for generating an ultrasound image, and may include at least one of a B mode image signal, a D image signal, and a 3D image signal. The first and second ultrasound signals are not limited thereto, and may also include various signals as long as they may be used to generate an ultrasound image.

Once a response signal is receiving from the object **99**, the ultrasonic diagnostic apparatus **300** compares the transmitted signal and the received signal, in **S300**.

Specifically, the ultrasonic transceiver **110** transmits the second ultrasound signal to the object **99** for estimation of a position of the ultrasonic probe **100**, receives the second response signal bouncing back from the object **99**, analyzes frequencies of the second ultrasound signal and the second response signal, and generate vector information about a relative position and speed of the ultrasonic probe **100** using the Doppler effect.

The Doppler effect is an effect observed when either or both of a wave source from which a wave begins and an observer who observes the wave are moving. According to the Doppler effect, the narrower the distance between the wave source and the observer is, the higher the frequency of the wave appears, and the farther the distance is, the lower the frequency appears. In the field of ultrasonics, the velocity of a blood flow or movement inside the object **99** is measured using the Doppler effect.

Referring to FIGS. **6A** and **6B**, if the ultrasonic probe **100** transmits the second ultrasound signal  $F_t$  to the object **99** and then makes a motion to the right, a frequency of the second response signal  $F_r$  bouncing back from the object **99** appears different from the frequency of the second ultrasound signal  $F_t$  due to the motion of the ultrasonic probe **100**.

Specifically, if the ultrasonic probe **100** transmits an ultrasound signal to an object and then moves away from the object, the observed frequency of the ultrasound signal is measured as being lower due to the Doppler effect, so in the case of FIG. **6A**, the frequency of the second response signal  $F_r$  received by the ultrasonic transceiver **110** is measured as being lower than the frequency of the second ultrasound signal  $F_t$ .

On the contrary, as shown in FIG. **6B**, if the ultrasonic probe **100** transmits an ultrasound signal to an object and then moves closer to the object, the observed frequency of the ultrasound signal is measured as being higher due to the Doppler effect. Accordingly, in the case of FIG. **6B**, the frequency of the second response signal  $F_r$  measured by the

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ultrasonic transceiver **110** is measured as being higher than the frequency of the second ultrasound signal  $F_t$ .

Furthermore, in the embodiment of the present disclosure, as shown in FIGS. **6C** and **D**, even while the ultrasonic probe **100** is being moved at an angle, the motion of the ultrasonic probe **100** may be estimated. Specifically, if the angle  $\theta$  formed between the object **99** and the ultrasonic probe **100** is known, the motion of the ultrasonic probe **100** may be estimated using the measurement result from the Doppler effect and the angle  $\theta$  with the object **99**. The ultrasonic probe **100** is often used while leaning at an angle as shown in FIGS. **6C** and **6D**, in which case the position of the ultrasonic probe **100** may be efficiently estimated.

FIGS. **6A-6D** show an occasion when a 1D array ultrasonic probe is used, and FIGS. **7A** and **7B** show the Doppler effect when a 2D array ultrasonic probe is used.

In the case of the 1D array ultrasonic probe, changes in angle are made only in the lateral direction and accordingly, a 1D motion may be estimated, but in the case of using the 2D array ultrasonic probe, angles of transmission of the ultrasound signal may be adjusted not only in the lateral direction but also in the elevation direction, thus enabling estimation of a 3D motion as shown in FIGS. **7A** and **7B**.

In the case of using the 2D array ultrasonic probe, a plurality of ultrasound signals may be transmitted and received with respect to three axes, enabling estimation of the 3D motion of the ultrasonic probe **100** using the Doppler effect for each axis.

If the Doppler effect of an ultrasound signal is observed due to the motion of the ultrasonic probe **100**, the controller **220** generates vector information of the ultrasonic probe **100** based on the Doppler effect and then estimates a current position of the ultrasonic probe **100** based on the vector information, in **S400**, **S500**.

Specifically, the ultrasonic diagnostic apparatus **300** may measure a relative speed of the ultrasonic probe **100** based on a change in frequency between the second ultrasound signal and the second response signal, and based on which, may estimate the position of the ultrasonic probe **100**. The vector information may include at least one of relative position information, speed information, and acceleration information of the ultrasonic probe **100**.

FIG. **8** shows an example of estimating a position of the ultrasonic probe **100**, and FIGS. **9A-9C** show a procedure of forming a freehand volume image based on the estimated position.

In the case of using the 1D array ultrasonic probe **100**, it is common to observe the Doppler effect only in the lateral direction, but it is possible to estimate a motion in another direction if an angle of a motion of the ultrasonic probe **100** and an angle of transmission/reception of the ultrasound signal are already known.

For example, as shown in (a) of FIG. **8**, if the ultrasonic probe **100** is moving forward while leaning at an angle ( $\Phi$ ) of about 45 degrees from the object **99** and an angle ( $\theta$ ) of transmission of a signal transmitted by the ultrasonic probe **100** to the object **99** is about 70 degrees, the speed in the moving direction may be estimated after compensation of an observed speed by  $1+(\cos 45^\circ \times \cos 70^\circ)=4.13$  times.

However, to estimate the position of the ultrasonic probe **100**, which is the 1D array probe, the angle ( $\theta$ ) formed between the ultrasonic probe **100** and the object **99** and the angle ( $\Phi$ ) of transmission at which the ultrasonic probe **100** transmits to the object **99** need to be maintained to some extents. It is because a correct compensation value may not be calculated if the two angles become 90 degrees.



In the embodiment of the present disclosure, with the first angle adjuster **151** for adjusting the angle ( $\theta$ ) formed between the ultrasonic probe **100** and the object **99** and the second angle adjuster **152** for adjusting the angle of transmission ( $\Phi$ ) at which the ultrasonic probe **100** transmits to the object **99**, the user may be able to move the ultrasonic probe **100** more easily. Furthermore, a fixer may be further included to fix the angle ( $\theta$ ) formed between the ultrasonic probe **100** and the object **99** and the second angle adjuster **152** for adjusting the angle of transmission ( $\Phi$ ) at which the ultrasonic probe **100** transmits to the object **99**.

Moreover, as shown in (b) of FIG. **8**, even while the ultrasonic probe **100** is being moved at an angle forward or backward, the position of the ultrasonic probe **100** may be estimated by transmitting and receiving the ultrasound signal. In this case, the 2D position and motion (to the front, back, left, right) of the ultrasonic probe **100** may be estimated using the Doppler effect occurring after two ultrasound signals (signals b and c) are transmitted and received in the left-right direction. In general, the ultrasonic probe **100** is often used while leaning forward and/or backward, and even in this case, the position of the ultrasonic probe **100** may be easily and efficiently estimated.

Once the motion of the ultrasonic probe **100** is estimated, a freehand volume as shown in FIGS. **9A-9C** may be formed by determining positions of images obtained based on the motion information and adjusting the intervals. For example, after ultrasound signals are transmitted and received at regular intervals or distances, cross-sections of the ultrasound images of the object **99** are obtained, and the freehand volume image may be created based on the position of the estimated ultrasonic probe **100**.

FIGS. **10** and **11** show a method for creating an ultrasound image using a 2D array ultrasonic probe, according to an embodiment of the present disclosure.

Referring to FIGS. **10** and **11**, the ultrasonic probe **100** may transmit and receive ultrasound signals to and from the object **99** while moving in a certain direction. The ultrasound signals transmitted and received may be the first ultrasound signal for creation of an ultrasound image or the second ultrasound signal for estimation of a position of the ultrasonic probe **100**. In other words, the ultrasonic probe **100** may obtain cross-sections of the object **99** by transmitting and receiving ultrasound signals at certain cycles or intervals, and simultaneously, estimate the current position of the ultrasonic probe **100**.

After that, as shown in FIG. **11**, the freehand volume image may be created based on the obtained cross-sections and estimated position of the ultrasonic probe **100**.

FIG. **12** shows sensor-equipped ultrasonic probes, according to an embodiment of the present disclosure.

Although the embodiment of the present disclosure may estimate the position of the ultrasonic probe **100** without attaching a sensor, a more correct position of the ultrasonic probe **100** may be estimated if the sensor **140** is attached.

The sensor **140** may include at least one of a position sensor, an angle sensor, a gyro sensor, an acceleration sensor, an acoustic sensor, a photo sensor, and a magnetic sensor, without being limited thereto. Although FIG. **12** shows the sensor **140** attached onto an external side of the ultrasonic probe **100**, the position of the sensor **140** is not limited thereto but may be attached onto the inside of the ultrasonic probe **100**.

Features and benefits of the present disclosure have thus far been described in connection with various embodiments of the present disclosure.

In the case of the conventional ultrasonic diagnostic apparatus, extra equipment needs to be attached to the ultrasonic probe to estimate the position of the ultrasonic probe, leading to an increase in costs, and there are many difficulties in creating an image with the 1D array probe.

However, in the case of the ultrasonic diagnostic apparatus in accordance with embodiments of the present disclosure, the current position of the ultrasonic probe is estimated using an ultrasound signal transmitted for creation of an ultrasound image without attachment of an extra sensor, so the position of the ultrasonic probe may be estimated more economically and effectively.

According to embodiments of the present disclosure, a current position of an ultrasonic probe may be estimated using an ultrasound signal to be transmitted for creation of an ultrasound image without having an extra sensor attached to the ultrasonic probe to estimate the position of the ultrasonic probe, so the position of the ultrasonic probe may be estimated more economically and effectively.

Although the present disclosure is described with reference to some embodiments as described above and accompanying drawings, it will be apparent to those ordinary skilled in the art that various modifications and changes can be made to the embodiments. For example, the aforementioned method may be performed in different order, and/or the aforementioned systems, structures, devices, circuits, etc., may be combined in different combinations from what is described above, and/or replaced or substituted by other components or equivalents thereof, to obtain appropriate results. Therefore, other implementations, other embodiments, and equivalents thereof may fall within the following claims.

What is claimed is:

1. An ultrasonic diagnostic apparatus comprising:  
an ultrasonic probe configured to:

transmit at least one first ultrasound signal and at least one second ultrasound signal to an object, and  
receive at least one first response signal which is a reflection of the at least one first ultrasound signal from the object and at least one second response signal which is a reflection of the at least one second ultrasound signal from the object;

an image processor configured to create an ultrasound image of the object based on the at least one first response signal; and

a controller configured to control the ultrasonic probe to transmit the at least one first ultrasound signal and the at least one second ultrasound signal at different times, wherein the at least one second ultrasound signal is transmitted from the ultrasonic probe by being steered by a preset angle in a lateral direction, and  
the controller is further configured to estimate a position of the ultrasonic probe based on the preset angle and a change in frequency between the at least one second ultrasound signal and the at least one second response signal.

2. The ultrasonic diagnostic apparatus of claim 1, wherein the controller is further configured to estimate a relative speed between the ultrasonic probe and the object based on the preset angle and the change in frequency between the at least one second ultrasound signal and the at least one second response signal, and to estimate the position of the ultrasonic probe based on the relative speed between the ultrasonic probe and the object.

3. The ultrasonic diagnostic apparatus of claim 1, wherein the controller is further configured to estimate the position of the ultrasonic probe based on a Doppler effect occurring



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between the at least one second ultrasound signal and the at least one second response signal.

4. The ultrasonic diagnostic apparatus of claim 1, wherein the controller is further configured to create vector information of the ultrasonic probe based on the at least one second ultrasound signal and the at least one second response signal, and to estimate the position of the ultrasonic probe based on the vector information.

5. The ultrasonic diagnostic apparatus of claim 1, wherein the at least one first ultrasound signal and the at least one second ultrasound signal comprise at least one of a brightness mode (B mode) image signal, a Doppler image signal, or a three dimensional (3D) image signal.

6. The ultrasonic diagnostic apparatus of claim 1, further comprising: a sensor configured to detect operation information about the ultrasonic probe,

wherein the controller is further configured to estimate the position of the ultrasonic probe based on the operation information.

7. The ultrasonic diagnostic apparatus of claim 6, wherein the sensor comprises at least one of a position sensor, an angle sensor, a gyro sensor, an acceleration sensor, an acoustic sensor, a photo sensor, or a magnetic sensor.

8. The ultrasonic diagnostic apparatus of claim 1, wherein the ultrasonic probe comprises a one dimensional (1D) array ultrasonic probe or a two dimensional (2D) ultrasonic probe.

9. The ultrasonic diagnostic apparatus of claim 1, wherein the at least one second ultrasound signal comprises a plurality of second ultrasound signals transmitted from the ultrasonic probe by being steered by different angles, and the at least one second response signal comprises a plurality of second response signals which are the plurality of second ultrasound signals reflected from the object, respectively.

10. The ultrasonic diagnostic apparatus of claim 1, wherein the image processor is further configured to create a volume image or panoramic image of the object based on the estimated position of the ultrasonic probe and the ultrasound image.

11. A method for controlling an ultrasonic diagnostic apparatus, the method comprising:

transmitting, by an ultrasonic probe, at least one first ultrasound signal to an object and receiving, by the ultrasonic probe, at least one first response signal which is a reflection of the at least one first ultrasound signal from the object;

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transmitting, by the ultrasonic probe, at least one second ultrasound signal to the object and receiving, by the ultrasonic probe, at least one second response signal which is a reflection of the at least one second ultrasound signal from the object;

creating an ultrasound image of the object based on the at least one first response signal; and

estimating a position of the ultrasonic probe based on the at least one second ultrasound signal and the at least one second response signal,

wherein the at least one first ultrasound signal and at least one second ultrasound signal are transmitted by the ultrasonic probe at different times,

the at least one second ultrasound signal is transmitted from the ultrasonic probe by being steered by a preset angle in a lateral direction, and

the estimating of the position of the ultrasonic probe comprises estimating the position of the ultrasonic probe based on the preset angle and a change in frequency between the at least one second ultrasound signal and the at least one second response signal.

12. The method of claim 11, wherein the estimating of the position of the ultrasonic probe comprises estimating a relative speed between the ultrasonic probe and the object based on the preset angle and the change in frequency between the at least one second ultrasound signal and the at least one second response signal, and estimating the position of the ultrasonic probe based on the relative speed between the ultrasonic probe and the object.

13. The method of claim 11, wherein the estimating of the position of the ultrasonic probe comprises estimating the position of the ultrasonic probe based on a Doppler effect occurring between the at least one second ultrasound signal and the second response signal.

14. The method of claim 11, wherein the at least one second ultrasound signal comprises a plurality of second ultrasound signals transmitted from the ultrasonic probe by being steered by different angles, and

the at least one second response signal comprises a plurality of second response signals which are the plurality of second ultrasound signals reflected from the object, respectively.

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